Why is it difficult to design innovative IT?

An agential realist study of designing
IT for healthcare innovation

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To Jenny

Some people think little girls should be seen and not heard.

But I think...

Oh, bondage! Up yours!

1, 2, 3, 4!

XRay Spex

Abstract

It may seem strange to claim that it is difficult to design innovative information technology (IT) in a time when the technological progress leaps forward like never before. However, despite the numerous opportunities that this rapid progress provides, we often design IT that is similar to existing artifacts, making IT design incremental rather than radical. At the same time, IT innovations are pointed out as crucial to meet the societal challenges we are facing, not least in the public sector, including a growing and older population, increasing demands from citizens and reduced tax revenues. This calls for us to better understand why it is difficult to design innovative IT. Previous research on this topic have mainly focused on human and social aspects, not paying close attention to IT. In this thesis, it is suggested that the sociomaterial theory agential realism can help shed light on the role of IT in innovative IT design, acknowledging the sociomateriality of IT. Thus, the overarching aim of this thesis is to apply agential realism on an empirical case in order to explore and explain why it is difficult to design innovative IT.

To fulfill the aim, a qualitative case study was conducted in publicly funded healthcare. The empirical case is an example of an attempt to design innovative IT in a healthcare context. The empirical material was generated through participant observations, including video recordings, and semi-structured interviews. The material was analyzed in several rounds, with and without a theoretical lens. In the agential realist analysis, IT has been viewed as entangled with the world. The analysis focused on what boundaries IT produced and how these boundaries were consequential for what was possible and impossible to design.

The thesis illustrates how IT is produced and productive in terms of both matter and meaning, and thus, is agential – IT makes differences in the world. What is possible to design is not only constrained by social structures but by the materiality of IT, what boundaries IT helps produce and the material-discursive practices that enact IT. Innovative IT design means to design material configurations that produce boundaries that are different from what have been enacted before and, thus, deviate from existing material-discursive practices. However, it is difficult to deviate from these since material-discursive practices are agential and define what boundaries are meaningful and legitimate. Hence, it is difficult to design innovative IT since innovative IT design has to both enact boundaries that deviate from agential material-discursive practices and also gain legitimacy. Through this explanation, the thesis makes an explanatory knowledge contribution which differs from and adds to earlier explanations. It also makes a contribution to conceptualizing the IT artifact by emphasizing IT as sociomaterial and providing examples of how IT can be understood as produced, productive, agential and entangled. Finally, the thesis also makes an empirical and methodological contribution in the sense that it demonstrates how an agential realist case study can be conducted in the field of Information Systems.

Foreword

Information Systems Development (ISD) is a research discipline within the Faculty of Arts and Sciences at Linköping University (LiU), Linköping Sweden. ISD is a discipline studying human work with developing and changing different kinds of IT systems in organisational and societal settings. The research discipline includes theories, strategies and policies, models, methods, co-working principles and artefacts related to information systems development. Different development and change situations can be studied as planning, analysis, specification, design, implementation, maintenance, evaluation and redesign of information systems. Focus is also on the interplay with other forms of organizational development, processes of digitalization and innovation. The discipline also includes the study of prerequisites for and results from information systems development, as e.g. institutional settings, studies of usage and consequences of information systems on individual, group, organizational and societal levels.

The ISD research at LiU is conducted in collaboration with private and public organizations. Collaboration also includes national and international research partners in the information systems research field. The research has a clear ambition to give distinct theoretical contributions within the information systems research field and relevant focus areas. Simultaneously, the research aims to contribute with practically needed and useful knowledge.

This work, *Why is it difficult to design innovative IT? An agential realist study of designing IT for healthcare innovation*, is written by Siri Wassrin, Linköping University. She presents this work as her licentiate thesis in Information Systems Development, Information Systems Division, Department of Management and Engineering, Linköping University, Sweden.

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During the very first months as a PhD student, I presented a thesis proposal and jokingly said that “I’m going on an adventure!”. Behind me, the screen was showing Bilbo Baggins excitedly running out of the Shire. Little did I know how accurate this analogy would prove to be and what highs and lows were in store for me on this adventure. It has taken me to exciting places and broadened my knowledge and horizons but, just like for Bilbo, it has also included some downright daunting and dark experiences. Sometimes, a storm is needed to make you realize you need to turn the ship around. Even though this adventure has had its ups and downs, I am proud of both the outcome and all the lessons learned along the way. I truly hope that this work can provide some *Aha!* moments for its readers, in the same way that I have enjoyed the excitement of seeing the world in a different light. However, these insights would not have been possible without a range of people which are entangled in this work. Here, I would like to direct my gratitude to everyone who in any way has contributed to making this thesis possible, however small it might be.

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Linköping, March 2018

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1. Introduction

This chapter introduces the background of the thesis. The research aim, research question and delimitations are presented and motivated. This is followed by an account of prospective knowledge contributions and target audiences. The chapter ends with an outline of the thesis.

Jennifer places three different devices in front of the users – a Virtual Reality (VR) headset, a tablet, and a laptop with a gaming steering wheel attached to the table. She welcomes the participants to the workshop and explains that the aim of the workshop is to test and play around with possible technologies to see what best meets the users' needs and requirements. The users engage with the different solutions with great enthusiasm. The VR headset is a new experience to them and results in much laughter as the person wearing the headset turns around to look at things that 'are not there'. The other two solutions are more familiar to the group. After testing all of the devices, Jennifer asks the group which one of the suggestions would best suit their needs. The group responds that the laptop with the gaming steering wheel is most appealing and appropriate. "But this solution is very similar to the one you have today?", Jennifer asks. "Yes", the group responds. Jennifer tries to point out the advantages of the other devices, but the users stand firm in their choice. After the workshop, Jennifer reflects: "You really learn a lot from the users, their expertise and needs, but gosh, is it difficult to introduce new ideas and solutions!"

1.1. Background

It may seem strange to claim that it is difficult to design innovative information technology (IT) in a time where innovation is the word on everyone's lips and technological progress leaps forward like never before. However, the story above, which is a semi-fictional account from the empirical material of this licentiate thesis, illustrates one of the difficulties of designing innovative IT. Despite the numerous opportunities that the rapid technological development provides, organizations often have a hard time to make use of these novelties (Gourville, 2006; Verganti & Öberg, 2013). For instance, many design projects result in IT solutions that are similar to previous designs. IT designers and developers often meet users who want new IT solutions to be similar to their old systems – but better (Gulliksen, 2006; Lientz & Rea, 2004). In this sense, users are often portrayed as conservative when it comes to new design (Heiskanen et al., 2007). Users may also resist new IT (Ali et al., 2016) and impede radical innovations in design projects (Lettl, 2007; Norman & Verganti, 2014). However, IT designers also contribute to the difficulties of designing innovative IT by relying largely on standard solutions and conventions in IT design rather than designing something new and different. That it is difficult to design innovative IT is also echoed in prior research. For instance, IT design and new technology investments in organizations tend to build on what went before rather than starting anew (Löwgren & Stolterman, 2004; Teece, 1996). That is, IT is used to 'pave the cow paths' – to automate or digitalize existing

practices rather than to more fundamentally reimagine and redesign both IT and organizational practices (Hammer, 1990). Organizations often want to solve problems in conventional ways by creating designs that address particular problems but that do not change how things are done or how to frame or view the problem at hand (Dorst, 2011). In this sense, IT design tends to reinforce the status quo rather than contributing to organizational changes (Cooper, 2000). This “resistance to new ways” and inertia exists not only in organizations but at all levels of society (Fagerberg, 2005, p. 9), making innovation and innovative IT design difficult.

However, this tendency to reproduce design is not new. Throughout history, humans have shaped their tools and artifacts to resemble their precedents. For instance, in our early days, we used our cupped hands to drink water, then we used shells that resembled the shape of our hands, then we made drinking vessels from clay or metal which were similar to the shell, and so on (Heskett, 2003). In this sense, design tends to be cumulative, incremental and follow certain continuities. That is, there is certain inertia to design. However, Heskett (2003) also acknowledges that humans have created more radical and disruptive designs without discernable precedents, such as the wheel. These radically innovative designs are rarer and more difficult to achieve than the incremental kind, including a high failure rate and a range of barriers to overcome (Sandberg & Aarikka-Stenroos, 2014). At the same time, there are high expectations in all sectors of society today that innovations will help us meet the many challenges that we are facing (Sandberg & Aarikka-Stenroos, 2014). Here, IT innovations are emphasized as key to manage these challenges. For instance, creative design is pointed out as the core of product innovation (Li et al., 2006) and innovative IT design and implementation of IT innovations are highlighted as essential to achieve organizational changes (Cooper, 2000; Fagan, 2004). Hence, there is a strong innovation discourse in society today, focusing on IT innovation and digital transformations.

Accordingly, IT innovation is both sought-after in society today but also a difficult endeavor. This also makes it a well-researched area. There is a vast amount of research on design, development and innovation, both in the field of Information Systems (IS) with specific foci on IT and IS contexts, but also in other academic fields. Furthermore, change and inertia are ancient conundrums that have intrigued researchers and philosophers for ages. This raises the justifiable question; What could yet another study on such a broad topic possibly contribute? To answer this question, we have to review prior research on these topics. Many explanations found in previous research focus on human and social aspects. For instance, Sandberg and Aarikka-Stenroos (2014) identify a range of barriers to radical innovation, including social, financial, societal, cultural, managerial and infra-structural obstacles, to mention a few. Other explanations focus on how people get ‘stuck’ in their ways and in their lines of thinking. Here, focus is often on individuals, their knowledge, problem solving practices and their conceptions of technology. People are depicted as being constrained by technological paradigms or frames, sociocultural regimes, institutions, discourses or prior ideas about IT design (Bijker, 1987; Crilly, 2015; Dosi, 1982; R. Jones, 2014; Norman & Verganti, 2014) which limit their possibility to design innovative

IT. Accordingly, human beings and social aspects are highlighted in explanations of why it is difficult to design innovative IT. However, technology is often bracketed out of the equation or seen as passive or superfluous (Orlikowski & Iacono, 2001). Pinch and Bijker (1987, p. 21) point out that in “analysis of technological innovation everything is included that might be expected to influence innovation, except any discussion of the technology itself”. Although this statement was made over 30 years ago, it is still relevant for IS researchers to conceptualize the IT artifact, as Orlikowski and Iacono (2001) point out (Orlikowski & Iacono, 2001). Hence, there is a knowledge gap in understanding *the role of IT* in the difficulties of designing innovative IT. Accordingly, by granting IT a more central role when studying why it is difficult to design innovative IT, we can improve our understanding of this challenge.

To bring IT to the center of analysis requires other approaches than what have been applied in prior research. Here, the recent sociomaterial stream in the IS field (e.g. Cecez-Kecmanovic et al., 2014) provides tools for a more nuanced study of innovative IT design where IT is not forgotten or ignored but given a prominent role in the analysis, while also accounting for social aspects. Sociomateriality is an umbrella term including several streams of research (Cecez-Kecmanovic et al., 2014; Orlikowski & Scott, 2008). Characterizing for sociomateriality is that it builds on a *relational ontology*. This means that this line of thinking challenges the duality and separation of the social and the material (Cecez-Kecmanovic et al., 2014). This can be contrasted to a substantialist ontology, which is dominating in IS research (Cecez-Kecmanovic et al., 2014), where it is assumed that people and things are separate and independent entities with inherent characteristics that interact and influence each other (Orlikowski & Scott, 2008). In a relational ontology, however, people and things come into being through relations and, hence, they do not pre-exist as separate entities (Cecez-Kecmanovic et al., 2014). This also means that “reality is not given but performed through relations” (Cecez-Kecmanovic et al., 2014, p. 811). Accordingly, sociomateriality is also characterized by the notion of *performativity*, i.e. that people and things, and their properties, are continuously performed. This means that sociomateriality is characterized by emergence or a becoming ontology, i.e. that the world is constantly emerging and coming into being and that stability is only temporary, if ever achieved (Cecez-Kecmanovic et al., 2014). Scott and Orlikowski point out the advantages of sociomateriality:

The broad banner of sociomateriality presents us with an opportunity for reconceptualization: from thinking about how technologies as discrete artifacts influence humans to examining how actions and relations are materially constituted in practice, and thus sociomaterial in nature. (Scott & Orlikowski, 2014, p. 874)

In this thesis, Barad’s (2007) theory *agential realism* is applied as a theoretical lens – a theory that can be positioned under the sociomaterial umbrella. In agential realism, IT artifacts and people are not considered as pre-existing and predefined entities but are continuously enacted and becoming determinate in and through material-discursive practices (Barad, 2007). By redefining the problem formulation from a human-centered perspective to foregrounding IT and its ongoing becoming and entanglement with the world, this opens

up for another solution space (Van de Ven, 2007), enabling potential knowledge contributions (elaborated in section 1.3.).

1.1.1. Innovative IT design in a healthcare context

The problem background illustrated above is also reflected in the healthcare sector. Today, there are political and public hopes, demands and expectations on IT innovations to meet societal challenges and needs, especially in healthcare (De Vries et al., 2016). These challenges include demographic changes with a growing and older population, increased demands and higher expectations from citizens (Frankelius, 2014) and increasingly informed and empowered patients (Herzlinger, 2006). Other challenges are reduced tax revenues and difficulties to find qualified employees (Lubanski et al., 2015). To ensure equal, high quality and highly available healthcare for all citizens in the future, innovation is considered a necessity to improve healthcare products and services (Frankelius, 2014; Sanandaji, 2012). Here, IT is often portrayed as a key feature to meet these challenges (Frankelius, 2014; Lubanski et al., 2015; Sanandaji, 2012; Thakur et al., 2012). For instance, “[d]ecision makers, patients, providers, etc. often present ICT applications in the health sector as one of the panaceas for reforming healthcare and improving healthcare costs, quality and efficiency” (Jordanova & Lievens, 24-26 November, p. 1). This view is also echoed by the European Union, the World Health Organization and in fields such as eHealth (Jordanova & Lievens, 24-26 November). Accordingly, the ability to design innovative IT becomes critical.

However, the healthcare sector also faces specific barriers to innovation. For instance, empirical research have demonstrated that radical innovation is especially difficult in large and old organizations (such as public healthcare organizations), which tend to only achieve incremental innovations (Castiaux, 2007). Public healthcare organizations are often characterized by a highly regulated, conservative, bureaucratic and hierarchical structure. This includes strong and institutionalized professions, expertise and knowledge intensive practices. They are also characterized by adherence to laws and rules, such as the Patient Act and rules governing what technology and medical devices can be used and how. There are also often longstanding practices and legacy systems and artifacts specific for the organization which contribute to making changes difficult. The requirement of evidence-based medical practices and artifacts also contribute to that health professionals are reluctant to experiment or change their practices since this can jeopardize patients’ health and well-being (Sanandaji, 2012). That is, although evidence-based practices aim to provide secure health practices, it also makes it difficult for health professionals to try out new ideas. Furthermore, public healthcare organizations have to consider many different stakeholders’ perspectives when innovating, which contribute to the complexity of this process. Accordingly, there are many obstacles for innovation in healthcare organizations.

Even though this sector faces many challenges, healthcare organizations are full of innovations, ranging from health information systems such as electronic health records and ePrescribing to medical devices used to diagnose and treat patients. This implies that

innovation is possible, although difficult, in this context. The strong need of IT innovations in healthcare, the organizational barriers to radical innovations and yet the proof that innovations are possible constitute an interesting context to study the abovementioned difficulties of designing innovative IT.

1.2. Research aim, research question and delimitations

Drawing on this background, this thesis builds on the assumptions that IT design often is reproductive and that it is difficult to design radically innovative IT. It also builds on the assumption that research on this topic has centered on human and social aspects and that IT has to be put in the foreground to better understand these difficulties. Thus, the overarching aim of this thesis is to apply agential realism on an empirical case in order to explore and explain why it is difficult to design innovative IT. Hence, the thesis addresses the following broad research question:

Why is it difficult to design innovative IT?

The research question can be criticized for its broad scope. However, this is an intentional choice. By applying agential realism, which is a high-level theory to conceptualize and explain the world in certain ways (Gregor, 2006), the broad question can contribute to our understanding and knowledge about why it is difficult to design innovative IT design in a general sense. That is, the conceptual shift from social and human-centered perspectives to viewing IT as pivotal can provide conceptual explanations, different from those we have today. Such conceptual explanations do not have to be limited to specific contexts and artifacts but can shed light on different types of instances in a more general sense. However, as indicated above, healthcare is considered an empirically suitable context in which to study the difficulties of designing innovative IT.

The application of agential realism as an analytical lens has implications for how the research question is operationalized and studied. The theory encourages researchers to study how IT is sociomaterial and makes a difference in the world (Scott & Orlikowski, 2014). This is also a key starting point in this thesis – to center the IT artifact and study its role in the difficulties of designing innovative IT, and thus, focus on the sociomateriality of IT. In this sense, the study focuses on design processes in which there are existing IT artifacts in the context, such as legacy systems, which may affect the possibility to design innovative IT. Furthermore, agential realist analyses focus on “examining the actions that perform particular phenomena” (Barad, 2003, p. 815). In this study, this entails a focus on what distinctions IT produces and how these distinctions are consequential for what is possible and impossible to design. By studying how IT contributes to performing particular phenomena, this can shed light on how IT is part of defining the possibilities and impossibilities for a specific design, i.e. the design space. In turn, these possibilities and impossibilities indicate the opportunities for innovative IT design to come into being or not.

The broad research question is also narrowed down by the following delimitations. First, this thesis addresses IT design (as a noun), i.e. the specifications of an IT artifact, and the process to create IT designs, i.e. to design (as a verb) (Ralph & Wand, 2009). Furthermore, this thesis focuses on the process of designing *innovative* IT, entailing that the IT design differs from prior and current designs (Dahlin & Behrens, 2005). In this sense, this study is not about innovation in general, but focuses on innovative *IT*. Moreover, the research question focuses on *radical* innovation rather than incremental innovation. This is because radical innovation is portrayed as more difficult, rarer and also more valuable in meeting societal challenges than incremental innovation (Sandberg & Aarikka-Stenroos, 2014). However, radical and incremental innovation are seen as a continuum and what is considered radical or not is a matter of social and historical negotiation (Csikszentmihalyi, 2014). Furthermore, innovation processes are often divided into three stages; creation, implementation and impact. The research question focuses on the creation of innovative IT design why the thesis is delimited to studying the creation phase. Hence, the study does not focus on implementation or impact of innovative IT designs.

The thesis is also delimited to study in-house IT design processes. As mentioned above, organizations have difficulties to benefit from the technological development today and also often have existing IT artifacts and practices that may limit their innovative ability. This makes it appropriate to study in-house IT design processes to account for this type of challenge. Here, in-house refers to that the organization in which the IT artifact is to be used is fully or partly involved in the IT design process, e.g. through involving employees and users. That is, the organization does not merely order an existing IT design but take part in the design process. However, the thesis does not focus on collaboration or user involvement in the IT design process *per se* even though these aspects relate to the IT design process and are present in the empirical case. These social aspects are not emphasized in this work but, instead, stand to the side in favor of the IT artifact. Accordingly, the IT artifact is put in the foreground and social processes are put in the background.

To answer the research question, a case study is conducted. The empirical case, referred to as *the driving simulator case*, is an example of an attempt to design innovative IT in a healthcare context. As mentioned above, to study the research question in a healthcare context is appropriate since this sector needs innovation, there are examples showing that successful innovation is possible in this context and there are also many barriers to innovation, making IT innovation difficult. The knowledge contributions and target audiences of this study are discussed in the following section.

1.3. Knowledge contributions and target audiences

The broad research question addressed in this thesis can lead to several knowledge contributions which are relevant for different audiences. First, the goal of the thesis is to contribute with an explanation of why it is difficult to design innovative IT in general. That is, by applying agential realism as an analytical lens, this thesis seeks to present a new perspective and understanding of these difficulties, which differ from earlier explanations

found in previous research. This prospective and explanatory knowledge contribution can be especially relevant for IS researchers interested in IT design and IT innovations. It may also interest researchers outside of the IS field with an interest in other ways to understand innovation in general. Furthermore, it could interest researchers who are particularly interested in how to design innovative IT in a healthcare context.

By applying agential realism as an analytical lens, the thesis can also contribute to conceptualizing the IT artifact. This contribution may interest and inspire fellow IS researchers who aim to take the IT artifact seriously in their research. The application of agential realism may also contribute to the sociomaterial research stream in the IS field. Here, it is pointed out that there are few empirical studies that fully apply sociomaterial theories (M. Jones, 2014). In this sense, this thesis can provide an empirical contribution in which agential realism, as a sociomaterial theory, is applied. Another challenge identified in sociomaterial IS research is that, due to the infancy of sociomateriality, it is unclear how these studies should be conducted methodologically, including how to analyze empirical material (Mutch, 2013; Scott & Orlikowski, 2013). Here, this thesis can contribute to an understanding of how agential realism can be applied in terms of methods, analysis and what researchers need to think of when conducting agential realist research in the IS field. In this sense, the thesis can also make a methodological contribution to the sociomaterial research stream in the IS field. This contribution is especially relevant for researchers in the sociomaterial research stream who are interested in how agential realism can be applied in the IS field.

The above paragraphs have focused on prospective knowledge contributions directed at an academic audience. However, new knowledge often also have implications for practitioners. Even though this thesis has a theoretical emphasis to a large extent, the aim of the theorizing and conceptual explanations is to make contributions that also can inform practitioners. Hence, the prospective and explanatory knowledge contribution mentioned above can be relevant for practitioners who in different ways work with IT design processes with the goal to innovative. This may include IT designers, IT developers, IT consultants and innovation process leaders both in the healthcare sector but also in other contexts. By providing a different understanding of why it is difficult to design innovative IT, new approaches to meet this challenge can be suggested.

1.4. Outline of the thesis

The thesis consists of six chapters, including this introduction. The aim of Chapter 1 has been to present the background and motivations for the study, introduce the research question, delimitations and knowledge contributions. Chapter 2 accounts for the theoretical foundation of the thesis, including prior research about and definitions of innovative IT design, and also a presentation of agential realism, which is the theory used as an analytical lens in the thesis. This is followed by Chapter 3 in which the research approach is described and discussed. This comprises methodological choices such as philosophical assumptions, research method, data generation techniques, analytical approaches, how the quality of the research can be evaluated and how the research was conducted.

In Chapter 4, the empirical material of the thesis is presented. Here, the driving simulator case study is described, in which participants aim to develop a new IT artifact to be used in healthcare. The chapter gives the reader an overview of the case and also highlights the design of the new IT artifact, identifying possible, impossible and uncertain designs. This is followed by Chapter 5 where the empirical case is analyzed and discussed in light of theory in order to answer the research question. Here, the IT artifacts in the case are studied as boundary-making apparatuses. This is followed by a discussion about the identified impossible, possible and uncertain designs. Finally, the analysis of the empirical material is discussed in light of previous research about design and innovation. The thesis ends with Chapter 6 in which the conclusions of the thesis are presented and the research question is answered. This is followed by a discussion about the thesis' knowledge contributions and implications for research and practice. The quality of the research is reviewed in a methodological discussion and the chapter ends with suggestions for future research.

2. Theoretical foundation

This chapter accounts for the theoretical foundation of the thesis. The initial sections focus on previous research about IT design and innovative IT, clarifying core concepts such as IT design, IT, and innovation. This is followed by a section that accounts for research about the difficulties of innovation and how these difficulties can be overcome. The final section focuses on agential realism, which is the theory used as an analytical lens in this thesis.

2.1. IT design

Design is ubiquitous in our everyday lives and also in human history. Human beings have shaped and formed nature in various ways for our survival and convenience since we were hunters and gatherers (Forty, 1986; Heskett, 2003). In this broad sense, design can be understood as a process of creating and shaping the world (Löwgren & Stolterman, 2004; Suchman, 2007), and today, there are few aspects of our lives that have not been designed (Forty, 1986; Heskett, 2003).

Design is studied in a diverse set of fields and these studies focus on different aspects of design, e.g. designed artifacts or *products* (including the characteristics and functionality of the design, how they work and affect their surroundings), or the design *process* (including the practices and methodologies of designing). Additionally, design is studied in different traditions or paradigms that view design somewhat differently, for example as positivistic problem-solving or as more constructivistic craftsmanship (Bannon & Ehn, 2013; Dorst & Dijkhuis, 1995). Furthermore, researchers in the IS field do not only research *about* design but also use design as a research approach, i.e. Design Science Research (DSR) (Hevner & Chatterjee, 2010; March & Storey, 2008). However, the research presented in this thesis is *about* design and does not use DSR as a research approach.

Design is also a ubiquitous and fundamental element in IS research. IS researchers are concerned with the development and use of *designed* artifacts, their organizational effects and, thus, most IS research address design more or less implicitly (Goldkuhl, 2004; March & Storey, 2008). In this way, design is an important aspect of IS research and should be attended to by IS researchers, both in terms of design as a process and a product (Benbasat & Zmud, 2003; Goldkuhl, 2004; Orlikowski & Iacono, 2001). Since this thesis seeks to investigate why it is difficult to design (i.e. the process) innovative IT (i.e. the product), focus will be on design as both a process and a product. Hence, the next section provides a definition of IT design as both a noun and a verb.

2.1.1. Definitions of IT design

Etymologically, design is derived from the Latin words *de* and *signare* which together means to designate, assign or mark out something (Krippendorff, 1989; Terzidis, 2007), e.g. to shape, make sense of and give meaning to things (Heskett, 2003; Norman & Verganti, 2014). However, in this thesis, focus is not on design of any ‘thing’ but on design in the IS

field and, more specifically, design of IT. Ralph and Wand (2009) argue that a precise and generally accepted definition of design is lacking in IS research. To remedy this situation, they suggest a definition of design drawing on their review of 33 different definitions of the concept. Ralph and Wand’s (2009) definitions are used in this thesis when referring to design as a noun and a verb (p. 108):

(noun) a *specification* of an *object*, manifested by some *agent*, intended to accomplish *goals*, in a particular *environment*, using a set of *primitive components*, satisfying a set of *requirements*, subject to some *constraints*;

(verb, transitive) to create a design, in an environment (where the designer operates)

The definitions are explicated in detail in the following paragraphs and the definition of design as a noun is illustrated in Figure 2.1. First, the *agent* is the entity or group of entities that create the design. Ralph and Wand (2009) argue that the agent often is one or more human beings but that it can also be non-humans, such as machines. *Design object* refers to the entity that is being designed, e.g. artifacts, systems and processes. The design object does not have to be a physical object. Next, *primitives* are the parts, components or elements that constitute or are to constitute the design object. That is, primitives are “the set of elements from which the design object may be composed” (Ralph & Wand, 2009, p. 108).

Figure 2.1. Conceptual model of design as a noun (model adopted from Ralph & Wand, 2009, p. 108)

Furthermore, a *specification* is “a detailed description of a design object’s structural properties” (Ralph & Wand, 2009, p. 106, emphasis in the original). Hence, a specification is a description of the primitives that constitute or are to constitute the design object and their connections. This means that the specification is not necessarily the same as the design object but could be a plan, idea, prototype, model or blueprint for constructing the object, or the actual design object itself. The point is that the properties of the design object are *specified*.

Next, *goals* are “what the design object should achieve” (Ralph & Wand, 2009, p. 108). Goals may be more or less explicit but Ralph and Wand (2009) point out that the agent must have some intentionality with the specifications. That is, design is not accidental

discoveries but there is always a purpose, objective or goal. However, this is not to be interpreted that the design goals always are unambiguous or articulated – they may be vague – yet the “design effort is always intentional” (Ralph & Wand, 2009, p. 106). Examples of goals are to solve a problem, meet certain needs, improve a situation or to create something new and useful (Friedman, 2003).

The *environment* is a context, situation or domain in which the design object is intended to operate or exist (e.g. an organization, an existing infrastructure, a physical space). *Requirements* refer to the agent’s expectations and desires that the design object are to “possess certain properties or exhibit certain behaviors” (Ralph & Wand, 2009, p. 107). These can be expressed in a requirements document but can also be implicit. Finally, *constraints* refer to restrictions or limitations on the design object and its properties and behaviors. According to Ralph and Wand (2009), these can be due to physical constraints (e.g. laws of physics) or mental abilities of e.g. the agent. These constraints may not be explicit (Ralph & Wand, 2009).

Now that design has been described in terms of a noun, the following paragraphs focus on design as a verb. Here, design is understood as a process that results in a specification of a design object. The goals, environment, primitives, requirements and constraints (described above) are input to the design process. These can be more or less explicit and may also emerge or change during the process. Ralph and Wand (2009) also emphasize the environment of the *agent* here, e.g. an organization, a team, a physical space.

Ralph and Wand (2009) point out that design is an activity and therefore not a well-defined phase of e.g. an IS development process. Instead, they argue that the start and end points of design are defined by the activities of the agent, i.e. when the agent specifies the properties of the design object. This means that design can start and stop several times in a development project and that design can occur throughout the whole development life cycle. Furthermore, this means that design activities can take place also after implementation, i.e. a user may change the structural properties of the object and is then, by definition, designing. In conclusion, Ralph and Wand’s (2009) definition of the design process exceeds traditional demarcations often used in development models such as the waterfall model or agile development methods.

Following these definitions of design as a noun and a verb, Ralph and Wand (2009) also define *design project* as “a *project having the creation of a design as one of its goals*” (p. 114, emphasis in the original). The authors’ definitions of design and design project will be used in this thesis as they provide conceptual clarity. However, the authors do not conceptualize and define IT. Hence, this is considered in the next section.

2.1.2. Conceptualizations of IT

In everyday terms, IT can be defined as “the technology involving the development, maintenance, and use of computer systems, software, and networks for the processing and distribution of data” (“Information technology,” n.d.). Orlikowski and Iacono (2001) argue that when IT artifacts are included in a phenomenon, it differs from other instances of that

type of phenomenon. That is, IT design differs from other types of design. The authors also point out that IT is often taken for granted and rarely conceptualized and theorized properly. To answer their call to conceptualize the IT artifact, the following paragraphs account for how IT is understood in this thesis.

Orlikowski and Scott (2008) divide research on IT into three research streams. In the first stream, IT is seen as a discrete and independent entity with inherent characteristics, which impact people and organizations in different ways. In this research stream, IT is often studied through variances to understand how IT affects and moderates specific phenomena (Orlikowski & Scott, 2008). The second research stream suggested by Orlikowski and Scott (2008) overlaps with Orlikowski and Iacono's (2001) *ensemble view*. Here, the IT artifact is considered as part of an ensemble or web of artifacts, people, social relations, organizations and contexts rather than a disparate and independent tool. That is, IT is seen as embedded in complex and dynamic social contexts and also as embodying social structures (Orlikowski & Iacono, 2001). This means that people, organizations and IT are seen as mutually dependent and that they shape and affect each other through continuous interaction. Hence, this stream often includes process studies to account for these interdependencies (Orlikowski & Scott, 2008).

The third research stream applies a sociomaterial view on the IT artifact. Here, "entities (whether humans or technologies) have no inherent properties, but acquire form, attributes, and capabilities through their interpenetration" (Orlikowski & Scott, 2008, pp. 455–456). This means that IT comes into being through specific relations or entanglements. Since a sociomaterial theory (agential realism) is applied in this thesis (elaborated in section 2.6. and 2.7.), a sociomaterial view of IT is adopted. This means that, rather than studying impacts or processes, the study will focus on relationalities, i.e. how seemingly given boundaries between IT and social aspects are coming into being. This entails that the IT artifact is not taken for granted as neutral or given but as recurrently enacted in specific entanglements.

Moreover, the sociomaterial view entails that IT artifacts are seen as emergent and changing over time in dynamic entanglements and, thus, are not static or independent. Instead of viewing IT through the lens of a stable and singular definition, agential realism enables us to study how IT is formed through practice in multiple ways. This view of IT also highlights the need to study the complex emergence of seemingly stable IT artifacts and how this emergence results in both social and material consequences. Accordingly, it also has implications for how IT design is understood. This means that the entities and elements in Ralph and Wand's (2009) definition above, e.g. design object and agent, are not considered separate and independent but as entangled and co-constituting each other.

Medical devices

The technology studied in this thesis' empirical material (presented in Chapter 4) is a medical device. This calls for a closer look at what is meant by this term and how it is similar to and differs from other technologies studied in the IS field. According to Fries (1997), a medical device is an instrument, apparatus, appliance or other article intended for use in

the diagnosis, prevention, monitoring, treatment or mitigation of diseases and injuries in human beings or other animals. Medical devices also encompass products used in relation to other conditions which are not diseases, such as pregnancy and impairments. This makes medical devices a heterogeneous type of products, ranging from simple tongue depressors to complex technologies such as pacemakers and surgical lasers. In this sense, medical devices differ from other technological artifacts in their intended use. Furthermore, a salient characteristics of medical devices is the importance of safety, efficacy and reliability (Fries, 1997). Even though these aspects are important also for other technologies, in the case of medical devices they can be the determining factor between life and death.

Medical devices often overlap with IT since they typically consist of computers that store, process, retrieve and exchange data. Today, many medical devices exist of both hardware and software. In this thesis, focus is on IT in general and medical devices that are embodied or enabled by IT in terms of hardware and software are considered examples of IT.

2.2. Innovative IT

Since this thesis investigates why it is difficult to design *innovative* IT, a closer look at innovation is needed. In the IS field, innovation has been studied in terms of e.g. *information systems innovation* and *digital innovation*. The definitions applied in these areas have been rather broad and highlight that something new is introduced (often in an organizational context) and that this ‘something’ is embodied or enabled by IT (Fichman et al., 2014; Lyytinen & Rose, 2003). There is also a more or less implicit link between design and innovation, creativity, and novelty. Design is sometimes highlighted as a fundamental aspect of innovation (Menguc et al., 2014) and some definitions of design emphasize that it is an activity of *inventing* (Stolterman, 1991) or of creating something *new* and useful (Friedman, 2003). Other authors argue that design does not have to be creative, novel or even “good”, but that designs also can be bad or only involve minor modifications of prior designs (Ralph & Wand, 2009). Accordingly, IT design, innovation, creativity and novelty are adjacent and overlapping concepts with relevance for the research question in this thesis, and are addressed in the following sections.

2.2.1. Innovation

Innovation is a major buzzword in our society today and is often uncritically viewed as innately good. However, to get some distance from the ‘sound of the times’, a historical retrospect shows us that, before the Renaissance, innovations were subversive acts of defiance of and deviations from tradition and the established order. Hence, it was considered a threat and was forbidden by law. Those who innovated were punished and the term innovator was used as an expression for those who committed heresy (Godin, 2015). Today, however, the term is highly taken for granted in all kinds of fields and is by Godin (2015, p. 3) described as “an attractive and unifying force because it has legitimacy and authority and is an incontestable value or ideology”. The point here is that although

the focus of this thesis is on innovative IT, innovations and attempts to innovate will not be considered as unproblematic or as incontestably valuable but rather critically examined.

As innovation is a topic studied in a range of fields, an array of definitions and perspectives exist. Innovation is often described in terms of change, i.e. as something new and/or improved (Baregheh et al., 2009). The aims of innovations are often described as to create added value and achieve advantages and differentiation in a competitive market (Baregheh et al., 2009) but also to meet societal challenges (Frankelius, 2014; Lubanski et al., 2015). Prior research has focused on a range of different types of innovation, e.g. products, processes, technologies, services (Baregheh et al., 2009), novelties in terms of markets, governance, strategy (De Vries et al., 2016; Fagerberg, 2005; Hartley, 2005) and also socio-cultural systems, ecosystems and institutional arrangements (Norman & Verganti, 2014). That is, the ‘something’ that is new and/or improved can vary. IS research about innovation has mainly focused on innovation processes, products, services, work practices and business models (Fichman et al., 2014; Lyytinen & Rose, 2003).

The innovation process is often roughly divided into three stages; creation, implementation and impact. In the first stage, ideas are generated and innovations are invented, created, designed and developed. In the second stage, innovations are implemented, commercialized, adopted and diffused (Baregheh et al., 2009). The third stage focuses on effects from the usage of the innovation (Fichman et al., 2014). These stages can be closely linked or overlap but can also be separated and distributed in time (Fagerberg, 2005). In the IS field, innovation studies have focused on adoption and diffusion and several authors argue that more research is needed about how innovative IT is created and developed (Fichman et al., 2014; Jha & Bose, 2016; Lyytinen & Rose, 2003; Zaman & Fiet, 2016). For instance, Lyytinen and Rose (2003) point out that the emergence of radical or disruptive IT innovations is a neglected area. This thesis focuses on innovative IT design and, thus, the creation stage of innovation will be the focal point here, not implementation or impact. Furthermore, as mentioned above, the thesis focuses on innovation both in term of the product and process, i.e. to design innovative IT.

Incremental and radical innovation

Innovations are often divided into incremental and radical innovation. Incremental innovation refers to continuous, cumulative and marginal improvements of existing solutions (Fagerberg, 2005). Here, the solution is developed within a given frame and enhances existing practices, i.e. “doing better what we already do” (Norman & Verganti, 2014, p. 82). Radical innovations, on the other hand, are revolutionary in the sense that they introduce new solutions (Fagerberg, 2005). This entails a change of frame and creates possibilities for “doing what we did not do before” (Norman & Verganti, 2014, p. 82). In this sense, radical innovation is often described as breakthrough, disruptive or competence destroying which denotes its discontinuity with the past, i.e. they break with traditions (Dahlin & Behrens, 2005; Norman & Verganti, 2014). Innovation researchers emphasize the need for both incremental and radical innovations. For instance, radical innovations usually have to be

improved incrementally to realize their full potential and become accepted (Fagerberg, 2005; Norman & Verganti, 2014).

Sandberg and Aarikka-Stenroos (2014) argue that radical innovations are more difficult and rare than incremental innovations and that attempts at radical innovation often fail. The authors identify a variety of radical innovation barriers including restrictive mindsets, lack of discovery competences, restrictive local culture, insufficient resources, lack of support from governments, the organization, and users, technological turbulence, and inappropriate or undeveloped infrastructures and networks. As mentioned in the introduction of the thesis, radical innovations are often emphasized as important in order to face challenges in society in general and healthcare in particular. Yet, these innovations have proved to be difficult to achieve and understanding of radical innovations are rather limited (Sandberg & Aarikka-Stenroos, 2014). Accordingly, since radical innovation is considered more difficult than incremental and radical innovations are needed in healthcare, this thesis focuses on why it is difficult to design *radically* innovative IT, as pointed out in the previous chapter. However, the sections below will describe both radical and incremental innovation since these are needed to understand innovation overall.

For something to be considered innovative, it has to be novel and unique, i.e. dissimilar from prior and current solutions (Dahlin & Behrens, 2005). But what is to be regarded as new, radical or incremental is not always straightforward. Csikszentmihalyi (2014) argues that novelty, uniqueness, creativity and innovation can only be determined through a social process of comparison, evaluation, interpretation, negotiation and legitimation involving actors and gatekeepers of a field and domain. This takes place in a historical context and results in a social agreement of what is considered new, unique, creative and innovative. In this sense, what is defined as an innovation or not, and what is considered radical or incremental can be seen as discursively constructed through e.g. rhetorical arguments (Sele, 2012). The stance taken in this thesis is that IT design can be considered more or less innovative by different actors and in different contexts, i.e. radical and incremental innovation are seen as part of a continuum.

Ethical aspects of design and innovation

Both innovation and design have inherent ethical aspects to them as they affect the world. For instance, Dunne and Raby argue that:

[A]ll design is ideological, the design process is informed by values based on a specific world view, or way of seeing and understanding reality. Design can be described as falling into two very broad categories: affirmative design and critical design. The former reinforces how things are now, it conforms to cultural, social, technical and economic expectation. Most design falls into this category. The latter rejects how things are now as being the only possibility, it provides a critique of the prevailing situation through designs that embody alternative social, cultural, technical and economic values. (Dunne & Raby, 2001, p. 58)

This excerpt is not to be interpreted that all affirmative or incremental design is to be considered undesirable and that we should only strive for critical or radical design. Instead, there are no clear answers to whether incremental or radical design is better. As Wilsford

(1994, p. 279) puts it: “There is, it would therefore seem, no general decision rule by which to prefer path-dependent change to the radical new trajectory - or vice versa /.../ So, in the end, we are left in the realm of values”. That is, as pointed out above, innovation and innovative design are not considered as unproblematic in this thesis. Along this line of thought, Walsham (2012) argues that IS researchers and practitioners should be concerned with ethical questions of IT, which includes innovative IT. Are we part of designing and making a better world with IT? Accordingly, what it boils down to is to design the kind of world we want to live in.

2.2.2. Innovation in the public sector and healthcare

The context in which innovation is studied is highlighted as an important aspect in understanding innovation (Baregheh et al., 2009). The empirical case in this thesis takes place in publicly funded healthcare and a few words are in place about prior innovation research in the public sector and healthcare. Research about innovation in the public sector is fairly new and still in its infancy, compared to the private sector (Fagerberg, 2005; Gallouj & Zanfei, 2013). However, as innovation has become a core matter in the public sector (Frankelius, 2014), more researchers focus on innovations in this context.

An important difference between innovation in the private and public sector is that the main goal of private sector innovation is to gain competitive advantage, whereas public sector innovation aim to increase public value in a broader sense. This can include economic value in the form of increased quality, efficiency and other improvements but also increased democracy and to improve citizens’ trust in the public sector, e.g. through better services or improved legal security (Hartley, 2005; Lubanski et al., 2015). However, according to Albury (2005), the public sector lacks the driving forces and pressures for innovation caused by market competition. Thus, there are few incentives and rewards for the organization and its employees to innovate (Albury, 2005; Borins, 2001).

Other challenges that the public sector faces in terms of innovation is that they often have to work with short-term planning and budgets which may inhibit innovation efforts (Albury, 2005). They are also subject to administrative burdens and delivery pressures and is characterized by a culture of risk aversion (Albury, 2005). One reason for this is that failed innovation attempts may be exposed by media and the political opposition (Borins, 2001). The public sector also tends to be slower in transforming their work and organization due to its conservative and bureaucratic organization (Albury, 2005; Bloch & Bugge, 2013).

Healthcare has proven to be a context in which it is especially difficult to innovate due to its conservative stance (Sanandaji, 2012; Topol, 2010), with the result that many innovation efforts fail (Herzlinger, 2006). This includes difficulties to change e.g. the practices of medicine, medical professionals, diagnosis and treatment methods, and the structure of healthcare organizations (Sanandaji, 2012; Topol, 2010). These innovations are hard to accomplish even when there is scientific evidence to back up the suggested changes (Topol, 2010). Hence, changes in healthcare are prone to take time (Sanandaji, 2012). At the same time, there are numerous examples of innovations in healthcare that have radically changed

healthcare organizations and medicine, ranging from X-ray machines to electronic health records.

Healthcare is conservative for a range of reasons. First, healthcare is highly controlled by laws and regulations which aim to produce secure healthcare services but which also tend to impede innovations (Herzlinger, 2006; Sanandaji, 2012). This includes medical laws, patient rights, and regulations of medical devices and public procurement, to mention a few. Second, there is a lower degree of experimentation than in other industries since this can jeopardize patients' well-being and safety (Sanandaji, 2012). Third, healthcare is hierarchical with several professions that may have noncoinciding or even conflicting perspectives or agendas. Since the implementations of innovations can alter work practices and power relations, innovations may pose threats to different stakeholders and their positions or even cause 'turf wars' between professions (Herzlinger, 2006; Sanandaji, 2012).

Apart from being conservative, healthcare also faces other challenges in terms of developing innovations, including lack of resources such as time and funding, lack of knowledge about technological possibilities, and negative attitudes towards commercialization and cooperation with other industries (Sanandaji, 2012). To conclude, although there is a great need for innovations in healthcare, there are also many barriers to achieve this. In the following sections, prior research about why it is difficult to innovate are presented.

2.3. Explanations of why innovation is difficult

There are many theories and explanations about why innovation is difficult. Even though these have been developed in different academic fields and with various lenses, they share many similarities. In most theories, the difficulty of innovation, or the stability or inertia of the status quo, is considered to be sustained by structures. Different authors refer to these restraining structures in different ways, e.g. as technological paradigms (Dosi, 1982), technological frames (Bijker, 1987), sociocultural regimes (Norman & Verganti, 2014), discourses (e.g. Foucault 1972, in R. Jones, 2014), path dependency (Garud et al., 2010) and design fixation (Jansson & Smith, 1991), to mention a few.

For instance, Dosi (1982) draws on Kuhn's paradigm concept and argues that a *technological paradigm* is a viewpoint which "determines the field of enquiry, the [technological] problems, the procedures and the tasks" (Dosi, 1982, p. 152). In this sense, the technological paradigm affects e.g. designers' understanding of how the design problem or situation should be defined, what means could be used to solve it and what solutions are feasible. Accordingly, the technological paradigm includes certain viewpoints on the problem and exclude others. This limits the designers' imagination and can make them "'blind' with respect to other technological possibilities" (Dosi, 1982, p. 153). This leads the designers down a specific *technological trajectory*, i.e. a specific problem solving pattern that is in line with the technological paradigm. In this sense, the technological paradigm influences how technology may change.

A concept similar to technological paradigm is Bijker's (1987) concept of *technological frame*. Bijker (1987) argues that a technological frame encompasses theories, implicit knowledge, goals and practices for defining and solving problems. This also includes a shared perception in a community of how a specific technological artifact should be understood and used (Bijker, 1987). For instance, IS developers are both enabled and constrained by their conceptions of existing IT and its capability (Lyytinen & Rose, 2003). A similar perspective is described by R. Jones (2010, p. 472) who, instead of speaking of paradigms, uses the term *discourse*, i.e. "socially informed systems of knowing, being and acting" including "words, acts, values, beliefs, attitudes, and social identities". Drawing on Foucault, R. Jones (2010, 2014) argues that discourses control and constrain our thinking, actions and creativity.

Yet another concept to explain the difficulty of innovation is *path dependency*, a concept similar to technological trajectories. Path dependency means that earlier design choices have long-term consequences for how technologies develop. This means that technological development emerges as a consequence of the history of the development process (Garud et al., 2010), i.e. the technology is historically embedded (Meyer & Schubert, 2007). Path dependency is often used to explain inertia, stability and the difficulty to reverse or change a technological trajectory or path (Meyer & Schubert, 2007). Thus, path dependent processes tend to lead to that designs are reproduced and that they follow a certain trajectory, leading to incremental change (Greener, 2002) and hindering radical innovation (Geels, 2004). Path dependency can even result in *lock-in*, i.e. where an inferior technology is used even though other, better options could be implemented (Wilsford, 1994). Geels (2004, p. 910) argues that "[a]s long as actors (e.g. firms) expect that certain problems can be solved within the existing regime, they will not invest in radical innovations and continue along existing paths and 'technical trajectories'".

A difference between the different concepts is the level of analysis where some concepts may encompass whole societies and stretch over a long time, whereas other concepts focus on local structures such as a technological trajectory of a specific industry or organization. Yet others focus on how structures enable and constrain the individual, such as designers' cognitive models or schemata (Lyytinen & Rose, 2003). In this thesis, all of these levels are considered to be mutually connected.

2.3.1. Design space and design fixation

Since this thesis focuses on innovative *design*, the following section presents how the difficulty of innovating has been explained in terms of design. Here, researchers focus on the *design space*, i.e. the possibilities and constraints that determine what can be designed or not (van Amstel et al., 2016). Hence, this concept share many similarities with the concepts mentioned in the previous section. The design space emerges through design actions including activities such as requirement elicitation, co-design workshops, prototyping and testing. However, these actions are also restricted by the design space, i.e. there is a dialectical link between design activity and design space. The forming of the design space

is also constrained by cultural and social trends, economic imperatives, technical and cognitive conditions (van Amstel et al., 2016). Another concept often used in studies about design is *framing*, which refers to the viewpoint or perspective that entails certain (implicit) assumptions about the design problem or situation (Dorst, 2011). That is, a frame is a way of seeing the situation and therefore it also affects the possibilities for action and what to design.

Designers start from what is known and what has been done before. Learning about prior designs, methods and interpretations of the design problem or situation can function as an inspiration or serve as analogies to inspire future designs (Crilly, 2015). However, designers often unintentionally limit themselves in terms of the variety of ideas, interpretations and potential solutions, which tend to reproduce designs (Crilly & Cardoso, 2017). Hence, prior knowledge and examples which could inspire designs can also constrain designers' creativity, leading to conservative design – a phenomenon known as *design fixation* (Crilly, 2015). Design fixation is described as “a state in which someone engaged in a design task undertakes a restricted exploration of the design space due to an unconscious bias resulting from prior experiences, knowledge or assumptions” (Crilly & Cardoso, 2017, p. 6). Another earlier definition describes design fixation as “a blind adherence to a set of ideas or concepts limiting the output of conceptual design” (Jansson & Smith, 1991, p. 3). However, some authors argue that designers may be *consciously* influenced by ideas or bodies of knowledge or even resist certain ideas intentionally (Youmans & Arciszewski, 2014). Overall, design fixation is portrayed as problematic since it can obscure and inhibit potential new ideas and designs, leading to a reduced variety in design solutions (Crilly, 2015) and even replication of designs (Youmans & Arciszewski, 2014). Furthermore, designers can also become fixated in terms of design process and methods (Crilly, 2015). Also users can become fixated, e.g. by already having a clear picture of the design they expect or from initial design proposals suggested to them (Crilly, 2015).

Design fixation can be divided into a narrow and a broad view. A more narrow view of design fixation focuses on designers' cognition and how they become fixated or their creative output blocked from the exposure of examples and existing designs. This makes designers rely on features from the examples and existing designs, limiting the novelty in their designs which results in designs that are similar to that of previous designs (Crilly, 2015; Youmans & Arciszewski, 2014). For instance, studies have shown that people have difficulties to see beyond artifacts' conventional functions which inhibit the possibility to design new functions (Crilly & Cardoso, 2017). On the other hand, starting out from existing designs may also save time and other resources, especially when promising potential solutions are not yet practically available or are too technically challenging (Crilly, 2015).

A broader view of design fixation does not only focus on the effects of examples and prior designs, but how knowledge and specific frames of references limit designers' creative output (Crilly, 2015; Youmans & Arciszewski, 2014). That is, designers rely “on a specific body of knowledge directly associated with a problem” (Youmans & Arciszewski, 2014, p. 129) and although designers' expertise and knowledge in a domain may enable them to

successfully perform within that domain, it is argued that this inhibits creativity beyond the domain (Crilly, 2015). Here, focus is not merely on the individual but on how ideas are embedded in society and organizations. For instance, Crilly (2015) argues that designers can become less flexible and replicate designs due to “paradigm-induced blindness” (p. 57) and domain expertise. Accordingly, this broader view has a lot in common with the concepts presented in section 2.3.

Youmans and Arciszewski (2014) point out that designers often fail to consider other knowledge and domains outside their own knowledge, experiences and assumptions. That is, they tend to frame the design problem or situation drawing on their previous knowledge which takes them down a similar design path as they have walked before, hence, inhibiting new ideas and designs. This is also described by Wiley (1998) who argues that people with a lot of domain knowledge tend to define and narrow down the search space which inhibits a wider search, decreasing the chance of finding appropriate solutions. In this sense, domain knowledge may act as a mental set and cause fixation. For instance, Wiley (1998) shows that people knowledgeable in a certain domain were less successful at creatively solving problems when the solution called for unconventional uses of an artifact. However, Wiley (1998) acknowledges the value and also necessity of domain knowledge in solving many problems. Having extensive knowledge and experience in a field makes problem-solving more effective and efficient since this allows experts “to infer missing information, make assumptions, and post constraints on a problem space” (Wiley, 1998, p. 728). At the same time, these aspects are also what may cause fixation and, thus, constitutes a disadvantage when solutions call for remote associations and combinations outside and/or between domains (Wiley, 1998).

2.4. Explanations of why innovations occur

The concepts presented in the sections above explain why innovation is difficult. However, changes and innovation do happen and most theories presented in the previous sections acknowledge that structures also can change, although often as a slow and arduous process. This is often seen as a dialectical process where structure and actors continuously affect and are affected by each other (cf. structuration theory and other dialectical practice theories). For instance, discourses change from our ongoing social practices (R. Jones, 2010, 2014) and technological frames change from actors’ interaction with each other and technologies (Meyer & Schubert, 2007). Similarly, the path dependency concept is accompanied by the concept *path creation* (Garud & Karnøe, 2001). Here, the agency of actors is highlighted and it is argued that designers can ‘mindfully deviate’ from the existing path (i.e. procedures and rules) and, thus, generate new paths (Henfridsson et al., 2009; Meyer & Schubert, 2007). By creating a new path, the current trajectory is discontinued and the emergence of a new paradigm is initiated, according to Dosi (1982). He refers to this as radical innovation. Incremental innovation, on the other hand, consists of smaller and continuous changes that follow the technological trajectory defined by the paradigm (Dosi, 1982). The following sections focus on how and why incremental and radical innovations

occur. Uncertainty and risk in innovation are also addressed, followed by an account of how radical innovation can be achieved.

2.4.1. Incremental innovation

Norman and Verganti (2014) and Verganti (2008) argue that incremental innovations often come from market- and user-centered approaches, such as user-centered design (UCD). These approaches share the assumption that innovation processes should start by involving and understanding the users, their needs, contexts, existing technologies and activities through e.g. observations and dialogue. It is assumed that this analysis will give the designers a unique insight that can lead to innovation. The designer's job is then to find technologies or methods that satisfies the identified needs. However, Norman and Verganti (2014) argue that these design approaches only lead to incremental innovation where technologies and meanings are part of existing technological paradigms and sociocultural regimes. That is, by working closely with the users, incremental enhancements of the design can be made through the iterative process of user dialogues, prototyping and testing. In this way, the design can be refined and optimized, user needs are met and the design is understandable and usable. Thus, user-centered design approaches help users improve what they already do, it does not radically change what they are doing or how they are doing it. In their studies of radical innovations, Norman and Verganti (2014) could not find any radical innovation that had been developed through approaches in which users' or society's needs were analyzed and taken as point of departure. This finding is also echoed by Menguc et al. (2014) who found that customer involvement in design only produced incremental innovations but hindered radical innovation.

According to Verganti (2008), the reason why user-centered design approaches only can lead to incremental innovations is because users are immersed in their sociocultural regime which makes them reproduce existing assumptions and meanings. That is, through user-centered design processes, users focus on what they already know, i.e. existing practices and technologies, which unconsciously limit potential design solutions. Dorst (2011) also argues that users often prefer not to change how they do things, their framework or the value they want from a design. Accordingly, by focusing on and addressing the users' existing problems and difficulties, the design will only lead to incremental improvements. Furthermore, the more designers interact with users and their contexts, technologies and activities, the more they become immersed in those assumptions and meanings and become 'trapped' in these sociocultural regimes. This in turn makes it harder for designers to envision more radical design solutions (Norman & Verganti, 2014). Important to point out, however, is that user-centered design approaches are not considered invaluable. Instead, Verganti (2008) highlights the importance of these approaches to refine and enhance designs. But in terms of radical innovation, they are limited.

2.4.2. Radical innovation

Norman and Verganti (2014) point out that many of the most radical innovations, such as cars, airplanes, indoor plumbing, electricity, Facebook and Twitter, did not come from user needs. Since this thesis focuses on radical innovation, the following sections provide two explanations of how radical innovation happens; *technology-push innovation* and *meaning-driven innovation*. In technology-push innovation, the ‘dominant designs’ and ‘normal technologies’ in a specific paradigm are rarely questioned until they are suddenly replaced by technological discontinuities or revolutions (Crilly, 2015). Garud et al. (2010) argue that these ‘exogenous shocks’ are needed to break out from lock-ins and to create new paths. Accordingly, this type of technological innovation breaks with the existing technological paradigm and initiates a new technological trajectory. Dosi (1982), Verganti (2008), and Norman and Verganti (2014) argue that technology-push innovation is not derived from user needs but comes from radical, technological changes and technological and scientific research, e.g. R&D efforts. Only after the technology is developed does the designer try to find suitable applications of the technology. The new technology is then ‘pushed out’ to different contexts (Norman & Verganti, 2014). Accordingly, in this perspective technological development is considered the primary driver of change and innovation.

Unlike technology-push innovation, meaning-driven innovation comes from changes in meaning (Norman & Verganti, 2014). Here, radical innovations are considered significant reinterpretations of prevailing meanings and, thus, also entail radical changes in the sociocultural regime or structure. Incremental innovations, on the other hand, encompass meanings that are in line with and conform to the current sociocultural regime (Verganti, 2008). For instance, altered meanings can radically change how existing technologies are used and understood without introducing new technology. Verganti and Öberg (2013) exemplify meaning-driven innovation with a reinterpretation of the meaning of robotics. They argue that there are two fundamental assumptions in the section of industrial robotics: 1) robotics are supposed to be efficient and increase productivity, and 2) there should be a distance between robots and humans to prevent injuries. However, in their example, these assumptions are challenged as *Robocoaster* is developed. This is a robot used in an amusement park where passengers program their ride before sitting down in the seats of the robotic arm. They are then lifted up and swung through the air by the robotic arm as programmed. Verganti and Öberg (2013) denote this as meaning-driven innovation as it challenges the meanings of robotics. The *Robocoaster* breaks with the two assumptions above since the robot is used for amusement rather than productivity and people are in close encounter with the robot. This change in meaning is accomplished without new technology but still entails an innovation, according to the authors. Meaning-driven innovation can also be coupled with technological changes, which Norman and Verganti (2014) refer to as *technology epiphanies*. This means that the innovation challenges both the dominant technological paradigm and sociocultural regime. The authors argue that this also makes this type of innovation both rare and risky since users tend to resist immense changes.

2.4.3. Uncertainty and risk in innovation

Uncertainty and risk are two other reasons why it is difficult to create more radically new designs. Fagerberg (2005) argues that uncertainty is inherent in all innovation processes. Making designs that are similar to existing designs entail less risk, both for users and designers (Crilly, 2015; Youmans & Arciszewski, 2014). For instance, Thakur et al. (2012) point out that if healthcare practitioners are familiar with a certain technology, it is more likely that they will find it useful and easy to use, and that their fear and uncertainty regarding the technology are reduced. In the case of designers, designs that are similar to existing designs make the designers more confident that these will work, that they can provide a safe product and also that they know what they have to deal with. Innovative designs, on the other hand, may solve many problems, but may also come with new problems which the designers or users are not familiar with (Crilly, 2015; Youmans & Arciszewski, 2014). Designers prefer to deal with the 'devil they know' (Youmans & Arciszewski, 2014), whereas more novel designs may involve changes and thereby risks – it is uncertain what the design may result in (Crilly & Cardoso, 2017). Accordingly, designers tend to go with the path of least resistance, especially in organizations where solutions that are timely, inexpensive and acceptable are preferred over superior solutions which take much time and resources to develop (Crilly, 2015).

Technological paradigms and sociocultural regimes create stability and familiarity by providing shared perceptions, norms, preferences and language etc., which help to coordinate groups of people (Geels, 2004). Accordingly, to deviate from them entails uncertainty (Garud et al., 2010; Wilsford, 1994). However, this also means that uncertainty implies a window for designing something radically new – an opportunity to deviate from the structures (Geels, 2004). When the structure is stable and aligned, few windows for radical novelty exist. However, if tensions, mismatches or contradictions are noticed, these can be used to open up for redefining the structure (Geels, 2004; Henfridsson et al., 2009). Geels (2004) also argues that it is difficult to alter one element in the regime without changing others. In this sense, uncertainty can both be seen as a hindrance to innovation in the sense that it generates risk aversion, but it can also open up for radically innovative designs.

To summarize, incremental innovations do not deviate from the technological trajectory or paradigm and do not radically change meanings and the sociocultural regime or discourses. Radical innovations, on the other hand, deviate from the existing order of things, either in terms of the technological paradigm or the sociocultural regime or discourse. This radical change entails uncertainty. The following section explore how such a deviation may occur.

2.4.4. Achieving radical innovation

As noted above, radical shifts do not come from developing solutions that fulfill existing needs since these types of analyses may trap the designer in existing sociocultural regimes. Rather, radical innovation is about envisioning and proposing new meanings and technologies. In this sense, radical innovation is to drive changes in sociocultural regimes (Verganti, 2008; Verganti & Öberg, 2013) and to produce variations in the inherited

structure (Csikszentmihalyi, 2014). This includes “exploring and challenging established understandings” (Brandt & Eriksen, 2010, p. 77), creating new interpretations and envisioning new possibilities and meanings by challenging dominant assumptions. This involves to imagine designs that are not asked for yet and requires a critical stance where assumptions, values and identities in the dominant sociocultural regime or paradigm are questioned and overcome (Verganti & Öberg, 2013).

However, to question assumptions in which one is immersed is not easy. Here, Verganti and Öberg (2013) argue that radical new meanings are co-generated. To be able to notice norms and underlying assumptions in the sociocultural regime in which one is immersed, people with outside perspectives are needed to help discern and bring light to these. Rather than involving users or other stakeholders who are immersed in their sociocultural regimes, the authors propose involving actors from outside the typical networks. These external interpreters are better suited to provide novel perspectives since they apply other frames for making sense of things. This can enable detours from the dominant sociocultural regime and may result in new meanings. This is also echoed by Jeppesen and Lakhani (2010) and Provost and Jarvenpaa (2014) who argue that marginal actors in a domain are better suited to come up with novel ideas. For instance, Jeppesen and Lakhani (2010, p. 1017) state that “marginality becomes an asset because the individuals are not burdened by prior assumptions”.

Similarly, Dorst (2011) highlights that reframing and reinterpreting “is a crucial part of design creativity, it allows design to take flight and move into truly new territory” (Dorst, 2010, p. 135). Designers often try to reframe the design situation in their search for a solution (Dorst, 2010) to avoid (implicit) assumptions about the design problem or situation (Dorst, 2011) or to avoid or break design fixation (Crilly, 2015; Dorst, 2010). For instance, designers can be exposed to alternative interpretations of the design problem or situation as this can help redefine and reframe them, which can open up for new solutions (Crilly, 2015; Dorst, 2010). This helps in rejecting and modifying existing ideas and designs which open up for more creative designs (Crilly, 2015).

Furthermore, innovations are often considered to be ‘new combinations’ of e.g. existing ideas, capabilities and resources etc. (Fagerberg, 2005; Schumpeter, 1934). By combining elements from different domains, regimes or discourses, these gradually change. For instance, R. Jones (2014) cites Fairclough who argues that “as producers and interpreters combine discursive conventions, codes and elements in new ways in innovatory discursive events they are cumulatively producing structural changes in the orders of discourse” (Fairclough, 1992, p. 97 in R. Jones, 2014, pp. 8–9). To use discourse creatively and contest them can create possibilities for imagining “new kinds of social identities and new ways of seeing the world” (R. Jones, 2010, p. 473) and also change power relations, reframe or open up for new activities that did not exist before.

Even when actors manage to break with the existing technological paradigm or socio-cultural regime, the recognition and diffusion of the innovation may not be immediate. For instance, since radically new meanings challenge and redefine the dominant sociocultural

regime, it takes time for people to understand the new meanings and connect them to their current experiences and contexts (Verganti, 2008). That is, to recognize the value of a radically new meaning, people need to “question their own dominant assumptions about what makes sense” (Verganti & Öberg, 2013, p. 88) and, thus, change their interpretative paradigm (Verganti & Öberg, 2013). Changes have to be “recognised as necessary, feasible and advantageous by a broader range of actors and institutions” (Berkhout, 2002, p. 2) which means that not all new combinations, visions and challenged assumptions are received favorably.

2.5. The role of materiality

Many of the theories described in the previous sections focus on how social structures make it difficult to innovate. However, there are also material aspects of technology that play a role in inertia. In the IS field, IT is often seen as embodying the social structures described above. This means that social structures, e.g. rules, values and assumptions, are built into the artifact during design and development (Orlikowski & Iacono, 2001). For instance, designers are part of a social, political, historical and cultural context (that is, e.g. the paradigms and discourses mentioned above) and carry with them certain knowledge, assumptions, theories, policies and values which are inscribed into the artifact (Goldkuhl, 2016; Sein et al., 2011; Walls et al., 1992). In this sense, the artifact is often considered as a carrier of or as embodying traces of these elements (Goldkuhl, 2016; Sein et al., 2011). This may also explain why much design mimics preceding designs. Cross (2001, p. 4) argues that this is not out of laziness but that preceding designs “actually contain knowledge of what the product should be”. That is, the implicit knowledge that resides or is embedded in the existing technology informs the designer of how to best shape the artifact and how it should be used. Cross (2001) argues that this is why many designs are copied from one example or generation to the next.

In addition, materiality offers certain possibilities but also presents constraints for what can be designed. That is, the design space is not merely cognitive but is also formed by e.g. the shapes and functions of objects and materials (van Amstel et al., 2016). However, even though prior research about the difficulties of innovation and innovative design has acknowledged materiality to some extent, materiality is described as a passive receiver of social structures or as a set of unproblematic givens. In this sense, the materiality of IT in the process of designing innovative IT has not been studied and theorized to a great extent. This thesis seeks to pay attention to the role of the IT artifact and materiality in innovative IT design. This is elaborated in the next section.

2.6. A sociomaterial approach

A ubiquitous question in IS research, that has been discussed since the infancy of the field, is how to come to grips with information systems’ simultaneous social and technological nature (Cecez-Kecmanovic et al., 2014). Orlikowski (2007) argues that IS research have either focused too much on technology, not paying attention to the social aspects or

focused too much on the social and human-centered perspective, hence, not paying attention to technological aspects. As mentioned above, Orlikowski and Iacono (2001) argue that the IT artifact tends to be black-boxed by IS researchers, i.e. taken for granted or conceptualized as unproblematic. In line with this, they advocate more theorizing about the IT artifact, as they see it as the core subject matter of the IS field.

The challenge to take both social and technological aspects into account in IS research has been approached by researchers in several ways, such as the sociotechnical systems approach and practice theory (Cecez-Kecmanovic et al., 2014). However, these approaches have always built on a “duality of the social and the technical” (Cecez-Kecmanovic et al., 2014, p. 810), i.e. the social and technological have been conceptualized as essentially separate. This assumption about duality is challenged by Orlikowski and Scott (2008) and Orlikowski (2007) who consider the social and material as inseparable. They argue that new ways to think of the social and material, and hence to reconceptualize the IT artifact, are needed to move beyond a dualistic view of them. One approach to do this is by applying a sociomaterial perspective (Cecez-Kecmanovic et al., 2014; Orlikowski, 2007; Orlikowski & Scott, 2008). As mentioned in Chapter 1, sociomateriality is an umbrella term including several streams of research (Cecez-Kecmanovic et al., 2014; Orlikowski & Scott, 2008) which has its historical roots in research traditions such as sociotechnical systems, Actor-Network Theory (ANT), practice theory, postmodernism, Science and Technology Studies (STS) and feminist technoscience, amongst others (Cecez-Kecmanovic et al., 2014). One theory that falls under the sociomaterial umbrella is *agential realism* (Barad, 1996, 1996, 1998, 2003, 2007), which is applied in this thesis. Here, technology and materiality are not rendered passive but make a difference in the world:

Matter is neither fixed and given nor the mere end result of different processes. Matter is produced and productive, generated and generative. Matter is agential, not a fixed essence or property of things (Barad, 2007, p. 137).

This is a promising theoretical stance if one wants to pay attention to the role of technology and technology’s materiality in innovative IT design. That is, as argued in the previous chapter, to change focus from social and human aspects to technological and material aspects and also to reconceptualize IT can lead to new understandings and explanations of why it is difficult design innovative IT.

2.7. Agential realism

Orlikowski and Baroudi (1991) divide IS theory into three broad research approaches which draw on different philosophical assumptions; positivist, interpretive and critical IS research. Agential realism fits in the latter category as it takes a “critical stance towards taken-for-granted assumptions” (Orlikowski & Baroudi, 1991, p. 6) and sees reality as historically produced and reproduced and, thus, constantly undergoing change (Orlikowski & Baroudi, 1991). Accordingly, as agential realism will be used as an analytical lens, the thesis can be categorized as critical IS research. The theory entails a new ontology and epistemology

(Barad, 2007) and includes many concepts and synonyms. These are presented in the following sections and summarized in Box 2.1.

2.7.1. A relational ontology

An essential point of departure in Barad's (2007) agential realism is the breakup with representationalism. Representationalism refers to the idea that there are, on the one hand, independently existing objects, things and individuals with inherent qualities and traits, and on the other hand, representations of these entities in the form of words, language and measurement. Here, objects and representations are ontologically distinct – objects are independent of and pre-exist their representations and are 'waiting' to be represented by words or measurement. In turn, words, language and measurement of various kinds are considered to mirror these pre-existing objects and individuals. Accordingly, representationalism divides the world into words and things, or more accurately into "representations and entities to be represented" (Barad, 2003, p. 804). This divide is taken for granted and seen as 'natural' in Western culture and is also the philosophical foundation on which both social constructionism and traditional realism build (Barad, 2003, 2007).

Barad (2007) suggests a relational ontology as an alternative to representationalism, i.e. that the world is composed of relations. But these relations do not presume any predefined entities, objects, terms, things or events – there are no pre-existing *relata*¹. There are no pre-established classifications such as human and nonhuman, subject and object, matter and meaning, with internal attributes (Scott & Orlikowski, 2014).

This relational ontology is the foundation on which Barad builds her agential realism. It may at first be hard to grasp this worldview as we are used to look at the world through a representational lens. It is also difficult to give the reader a good example since every example by default will divide the world into 'things'. A far from perfect metaphor is to view the world as water. We cannot distinguish where one part of the water starts or stops – it is all relations. We cannot break the water down into molecules or atoms as this would be to assume that there are things (e.g. atoms) with inherent properties. Accordingly, this relational ontology rejects the separation of the world into words, people and things – instead, all is relations:

[“]Each thing, including each person, is first and always a nexus of relations” (Slife 2004, p. 159). Qualities, properties, and identities do not reside from something inherent or “inside” a substance but instead depend on how, when, and where they are related to each (Emirbayer 1997, p. 287). (Scott & Orlikowski, 2014, p. 878)

This line of thinking challenges the duality and separation of the social and the material (Cecez-Kecmanovic et al., 2014). In IS research, the dominating view is that humans and IT are separate and independent entities with inherent characteristics that interact and influence each other (Cecez-Kecmanovic et al., 2014; Orlikowski & Scott, 2008). In a relational ontology, however, humans and IT (and other entities) come into being through

¹ *Relatum* (plural *relata*): one of the objects between which a relation is said to hold (“*relatum*,” n.d.)

relations and, hence, they do not pre-exist as separate entities (Cecez-Kecmanovic et al., 2014).

In her descriptions of relations, Barad (2007) uses a range of different terms interchangeably, such as *intra-actions*, *entanglements*, *phenomena*, *relationalities*, *(re)configurings* or *(re)articulations*. My interpretation of her varying vocabulary is that all of these terms signify relations (going back to the relational ontology), the point being that entities come into being through different relations. For instance, the term *intra-action* can be contrasted to the more usual term interaction. The latter term assumes that there are distinct entities or relata in between which some kind of relationship or contact is established. Intra-action, on the other hand, does not presume distinct entities but that distinct entities *emerge* through intra-actions, i.e. a specific set of relations result in an entity.

Accordingly, entities (such as humans and IT) come into being through specific intra-actions. These intra-actions are continuously performed in practice where practice is understood as the ongoing process of configurings and reconfigurings, i.e. the forming and reforming of different relations (Barad, 2007). This means that agential realism is characterized by emergence and performativity – that the world is continuously coming into being – “reality is not given but performed through relations” (Cecez-Kecmanovic et al., 2014, p. 811). Put differently, intra-actions form and exist in practice and thus enact (perform) different entities. As the word indicates, *intra-action* is a doing – practice. This means that entities become determinate in and through practice. Hence, intra-actions exist in practice and practice is constituted by intra-actions (Barad, 2007).

Performativity means that the world is constituted in and through practice. However, the world’s constant ‘state’ of becoming does not mean that there is no stability in the world. Instead, stability or structure are ongoing accomplishments (Scott & Orlikowski, 2014). This also means that practices are open and ongoing. They do not simply reproduce or replicate a certain structure, but perform the world through different configurations (Barad, 2007). In this sense, the structures described earlier in this chapter (such as paradigms, regimes, discourses etc.) are iteratively reproduced and reconfigured through continuous intra-actions. This entails that structures and stability are only temporary and are continuously performed (Cecez-Kecmanovic et al., 2014).

The relationality and performativity of agential realism alter the research gaze from focusing on how things *are* to how these *come into being* and what differences their specific way of becoming make, i.e. a shift towards questions of intra-actions, practice and doings (Barad, 2007). In this thesis, this entails that entities – especially IT, but also people – are not taken for granted as given but studied in terms of their entanglements, i.e. their intra-actions by which they exist and come into being. It also entails a focus on how the specific becoming of IT is consequential for how other entities are becoming, i.e. how IT makes a difference in the world. Accordingly, agential realism makes it possible to center on IT when analyzing why it is difficult to design innovative IT. In this sense, this theory can provide new explanations of a well-researched topic and question and add to our understanding of why innovative IT design is difficult.

2.7.2. Phenomena and apparatuses

Two central concepts in agential realism is *phenomena* and *apparatus*. Phenomena was mentioned in the prior section and refers to “relations without preexisting relata” (Barad, 2003, p. 815) which constitute reality. Accordingly, phenomena are relations/intra-actions/entanglements. However, in our everyday lives, we do not experience relations without relata but we encounter what appears to be separate entities with clear boundaries. As described above, these entities and their boundaries are not static nor given, but brought into being through practices. The boundaries and properties of entities become determinate through specific relations. Consequently, ‘things’ only exist *in* and as part of phenomena, not as “things-in-themselves or things-behind-phenomena” (Barad, 2007, p. 140).

Barad (2007) illustrates this with an example from physics. By the end of the nineteenth century, physicists debated the nature of light. Some authorities on the subject claimed that light was a wave, whereas others argued that it was a particle. However, experiments showed that light sometimes manifested as a particle and at other times behaved as a wave. What made the difference was the experimental setup or *apparatus*, i.e. how the device and practice for measuring light was designed: “every time a given apparatus was used, the same behavior—whether particle or wave (not both)—resulted” (Barad, 2007, p. 105).

In this example, the nature of light varies depending on the design of the measurement apparatus – when one apparatus is used, light is enacted as a wave and when another apparatus is used, light is enacted as a particle. However, the practice of measuring also encompasses the scientist operating the device and tinkering with the settings. Hence, the apparatus is not reduced to the measuring device but includes the practices of measurement. What is important here is that the apparatus creates a *boundary* – an *agential cut* – within a set of relations, making a temporary distinction between the apparatus and the entity. This makes it possible for us to think of the particle as a self-contained object. However, the particle only becomes determinate and bounded in relation to a certain apparatus – in this case specific measuring equipment and measuring practices. Hence, another important aspect is that *the apparatus is part of the phenomenon*. The particle cannot become determinate without the apparatus and the apparatus is inseparable from the object that is produced – both object and apparatus constitute the phenomenon – they are intra-acting. This means that the apparatus is part of the entity being produced. In addition, this also means that when the apparatus is changed, the phenomenon changes. Barad (2007) argues that “different intra-actions produce different phenomena” (p. 58) and that “*the nature of the observed phenomenon changes with corresponding changes in the apparatus*” (p. 106, emphasis in the original). For instance, by changing the measurement devices and practices, light manifests as a wave instead of particle. In this way, light is multiple and dynamic – both particle and wave. Hence, phenomena are not static but dynamic – changing with various apparatuses. Or put differently, phenomena are continuously produced in different intra-actions. Intra-actions change and are iteratively (re)configured – an ongoing process of intra-activity, which makes phenomena dynamic.

What does this mean for studying the difficulties of designing innovative IT? This entails that the IT artifact (and other ‘entities’ such as humans) cannot be seen as separate, static and pre-existing entities, but as entities that become determinate – come into being – in ongoing intra-actions with certain apparatuses. That is, to see IT as a phenomenon in an agential realist sense is to acknowledge that we are not to merely focus on e.g. the IT artifact as our object of study, but to pay attention to the *phenomenon*, i.e. the artifact and the apparatuses which produce and determine how the artifact is enacted. It also entails that we can study IT as an apparatus which is part of enacting specific phenomena. In this sense, the apparatuses cannot be separated from the phenomenon. Put differently, since agential realism builds on a performative worldview, this entails that we have to pay attention to the way phenomena is enacted by different apparatuses.

Furthermore, the emergent and dynamic nature of agential realism also has implications for understanding novelty and innovation. Barad (2014, p. 168) argues that “[t]here is nothing that is new; there is nothing that is not new”, thus, denoting that the world is constantly coming into being through different intra-actions. This ongoing intra-activity is both stabilizing and destabilizing which means that there always are possibilities for new intra-actions to form and for practices to perform something different. Through changing intra-activity or the (re)configuring of apparatuses, new possibilities and impossibilities form:

But neither is anything and everything possible at any given moment. Indeed, intra-actions iteratively reconfigure what is possible and what is impossible—possibilities do not sit still. One way to mark this is to say that intra-actions are constraining but not determining. But this way of putting it doesn’t do justice to the nature of “constraints” or the dynamics of possibility. Possibilities aren’t narrowed in their realization; new possibilities open up as others that might have been possible are now excluded: possibilities are reconfigured and reconfiguring. (Barad, 2007, p. 177)

In this sense, apparatuses are not arbitrary, but neither are they deterministic. Instead, “*apparatuses are the material conditions of possibility and impossibility of mattering*; they enact what matters and what is excluded from mattering” (Barad, 2007, p. 148, emphasis in the original). Imagine for instance that the apparatus for measuring light as a particle never had been enacted. Then light would never have been determined as a particle – it would not have been possible to understand light as a particle. I find this thought intriguing in the area of innovative IT design as this line of thinking opens up a way to study what is considered possible and impossible in the design situation. What apparatuses determine what is included and what is excluded – what is possible and not? In this sense, agential realism can help us understand the difficulties of innovative IT design in new ways.

Apparatuses are material-discursive and boundary-making practices

Above it was stated that apparatuses are an essential part of phenomena and for producing distinct entities. But what are apparatuses? In her description of apparatuses, Barad (2007) uses several synonyms, such as *material practices*, *discursive practices*, *material articulations*, *physical arrangements*, *material-discursive practices and concepts*. Going back to the example of measuring light, the apparatus consisted both of the equipment used to perform the measurements, the persons doing the measuring and their measuring practices, including their knowledge

about how measurements should be done. All of these are part of producing the boundary that makes light distinct as a particle or wave. Barad (2007) highlights that apparatuses are always both material and discursive and consist of specific physical arrangements (elaborated in section 2.7.3.). In this thesis, apparatuses and material-discursive practices will be used interchangeably.

Apparatuses are boundary-making practices which means that different material-discursive practices produce different boundaries, i.e. different entities become determinate. In the example of measuring light, it was shown that one specific apparatus determined light as a wave whereas another apparatus determined light as a particle. What the different apparatuses do is to include some things while excluding others – they include and exclude different relations. This results in different phenomena, although both fit under the term ‘light’:

The two different apparatuses effect different cuts, that is, draw different distinctions delineating the “measured object” from the “measuring instrument.” In other words, they differ in their local material resolutions of the inherent ontological indeterminacy. There is no conflict because the two different results mark different intra-actions. (Barad, 2003, p. 816)

Put differently, the apparatus determines and enacts a specific entity. This also entails complementary indeterminacies – exclusions – which are not becoming determinate (Barad, 2007). Again, this can be related to the study of innovative IT design. What designs are enacted and what designs are excluded from being enacted? What boundaries are IT part of including and excluding? What apparatuses perform these inclusions and exclusions?

Apparatuses are both productive and produced

As noted above, apparatuses produce boundaries, i.e. they are *productive*. However, important to point out is that apparatuses are also *produced*. They do not exist before or outside phenomena, neither are they pre-existing entities which ‘cause’ phenomena. Instead, they are *part of* and is emerging together with phenomena (Barad, 2007):

A phenomenon is a specific intra-action of an “object” and the “measuring agencies” [apparatuses]; the object and the measuring agencies emerge from, rather than precede, the intra-action that produces them (Barad, 2007, p. 128, emphasis in the original).

As apparatuses are not pre-existing, this means that they are produced by other material-discursive practices. That is, in the example of measuring light, the equipment used to perform the measurements, the persons doing the measuring and their measuring practices, including their knowledge about how measurements should be done, are all produced by various material-discursive practices. This means that apparatuses always are “open-ended practices” (Barad, 2003, p. 816). They do not have inherent outside boundaries – it is not possible to say where the apparatus starts or stops. This in turn means that it is impossible to reach closure:

Apparatuses have no inherent “outside” boundary. This indeterminacy of the “outside” boundary represents the impossibility of closure—the ongoing intra-activity in the iterative reconfiguring of the apparatus of bodily production. Apparatuses are open-ended practices. (Barad, 2003, p. 816)

For instance, first, we can focus on the apparatuses that enact light, e.g. the measuring device. Next, we might study what apparatuses produce the measuring device as a determinate entity. This can then be followed by subsequent studies of how those apparatuses are produced. In this way, the apparatus will always be open-ended, lacking an outside boundary – they are always enacted by other apparatuses. This also means that material-discursive practices are entangled and productive of each other. The open-endedness entails a challenge in delimiting the scope of analysis, which I comment on in section 3.4.2. and 6.4.

2.7.3. Matter and meaning

As agential realism builds on a relational ontology, this also has implications for how matter and meaning are conceptualized. Here, matter does not refer to a fixed substance as this would assume pre-existing boundaries and independently existing objects and things. Instead, Barad (2007) describes matter as a doing – intra-actions which are configured and reconfigured in an ongoing, dynamic, iterative, stabilizing and destabilizing process of becoming. She terms this intra-activity. Accordingly, matter is not mediating or supporting practice, but constitutes practice (Scott & Orlikowski, 2014). Practice is how phenomena is continuously materializing – becoming.

Also meaning is reconceptualized in agential realism. Barad (2007) argues that things that we often characterize as ideational, such as concepts, instead are “specific physical arrangements” (p. 109) or “particular material articulations of the world” (p. 139). Barad (2003) exemplifies by describing the concept ‘position’. This concept becomes meaningful in a specific physical arrangement of e.g. a measuring practice. For instance, position can be determined if a ruler is attached to a surface so that “a fixed frame of reference” (Barad, 2003, p. 814) is established in which ‘position’ can be specified. Hence, the concept ‘position’ only becomes determinate and meaningful in a specific practice that entails specific physical arrangements:

[C]oncepts are meaningful, that is, semantically determinate, not in the abstract but by virtue of their embodiment in the physical arrangement of the apparatus. (Barad, 2007, p. 117)

In their study of hotel evaluations in the travel sector, Scott and Orlikowski (2014) show how anonymity as a concept becomes meaningful and semantically determinate in different ways in two different practices. They argue that anonymity often is considered a social construct – an idea or ideational concept. However, the authors (2014, p. 875) show how this phenomenon is not fixed nor a binary state but “a dynamic material enactment” (Scott & Orlikowski, 2014, p. 875). In one example, anonymity was enacted through a practice including professional hotel reviewers who checked in at hotels under false names so that hotel staff would not treat them differently than a regular guest (what I call ‘face-to-face-anonymity’). After the reviewers conducted their evaluation of the hotel, they revealed their true identity to the hotel staff, giving them feedback on the hotel experience. This example is contrasted to another hotel review practice where evaluations were performed on an online social media website. In this example, regular hotel guests checked in at hotels with

their true name but later submitted anonymous reviews on social media (what I call ‘behind-the-screen-anonymity’). Both practices are examples of ‘anonymity’ but the concepts are materially enacted by different practices – embodied in different ways. The practices entail different physical arrangements, e.g. a ‘face-to-face-anonymity’ versus a ‘behind-the-screen-anonymity’ (i.e. they consist of different intra-actions). That is, ‘anonymity’ becomes meaningful, determinate and performed differently in different practices. Hence, “anonymity is multiple, dynamic, and sociomaterial”, not “largely social and singular attribute of some agent or system” (Scott & Orlikowski, 2014, p. 887). Furthermore, the practices which perform ‘anonymity’ is inseparable from the concept – together they constitute a phenomenon. Just as ‘light’ is produced in different ways depending on the apparatus, so is ‘anonymity’ produced differently depending on the apparatuses. The meaning of ‘light’ or ‘anonymity’ is defined in their physical arrangement.

But what difference does it make to consider concepts as materially enacted? In the study by Scott and Orlikowski (2014), the different embodiments of anonymity led to different consequences for the travel and hotel industry. In the case of the professional hotel reviewers, being anonymous during hotel visits reassured that they did not get any special treatment than the regular guest. Hence, this embodiment of anonymity led to a greater credibility and standardization in their reviews. In the case of the social media website, anonymity led to that reviewers could share their hotel experiences but it made it ambiguous if the online reviews were credible or not. In turn, this led to a redistribution of accountability, i.e. who is to be responsible for the accuracy of online reviews and to verify if the reviewers had actually visited the hotel. Hence, the different enactments of anonymity were essential for knowledge production about hotels and resulted in both increased and decreased credibility of the reviews. In this sense, the apparatuses and specific physical arrangements producing phenomena are central to understanding the effects of those material-discursive practices. This reconceptualization of meaning can be fruitful in the IS field where we grapple with issues often considered ideational, immaterial or intangible, such as software, language or social structures (Scott & Orlikowski, 2014). It can help us study the materiality of these ‘intangibles’ – how they are produced and what their specific enactments entail.

So far, it has been stated that matter and meaning emerge through material-discursive practices. It should also be pointed out that subjects – humans – also are coming into being in the same way. There is no given distinction between ‘subject’ and ‘object’:

To be entangled is not simply to be intertwined with another, as in the joining of separate entities, but to lack an independent, self-contained existence. Existence is not an individual affair. Individuals do not pre-exist their interactions; rather, individuals emerge through and as part of their entangled intrarelating. (Barad, 2007, p. ix)

This means that, in the same way that we cannot take IT artifacts for granted or as given, we cannot take subjects – people, users, practitioners, etc. – as pre-existing or predefined.

Discourse and discursive practices

Meaning is not created by the thoughts or actions of individuals but is made possible through material-discursive practices (Barad, 2007). Here, discourse does not refer to language, signifying systems, conversations or speech acts. To consider discourse as ways of describing things in the world is to apply a representational view of the world. Neither is discourse and discursive practices reduced to human practices. Instead, Barad argues that:

Discourse is not what is said; it is that which constrains and enables what can be said. Discursive practices define what counts as meaningful statements. (Barad, 2007, p. 146)

Again, Barad comes back to that meaning is formed in practice. She defines discursive practices as “*specific material (re)configurings of the world through which the determination of boundaries, properties, and meanings is differentially enacted*” and that “*apparatuses are discursive practices*” (Barad, 2007, p. 148, emphasis in the original). That is, just as concepts always are material, so are discourse and discursive practices: “Meaning is made possible through specific material practices” (Barad, 2007, p. 148).

To conclude, concepts, language and meaning are always material, enacted through practice. Also, matter is an ongoing, dynamic and iterative process of becoming – configurings and reconfigurings. Hence, concepts, language and meaning (as material) are also ongoing processes of materialization. The point is that apparatuses and practices are always both material and discursive. In this sense, all practices are material-discursive:

The relationship between the material and the discursive is one of mutual entailment. Neither discursive practices nor material phenomena are ontologically or epistemologically prior. Neither can be explained in terms of the other. Neither is reducible to the other. Neither has privileged status in determining the other. Neither is articulated or articulable in the absence of the other; matter and meaning are mutually articulated. (Barad, 2007, p. 152)

Going back to the examples above, both the materiality and meaning of these are becoming determinate in practice – through specific intra-actions. ‘Light’ and ‘anonymity’ become determinate, both in terms of meaning and matter, in and through their respective apparatuses. Furthermore, these boundary-making practices are not to be seen as problematic, but as essential for meaning-making:

Boundaries are not our enemies; they are necessary for making meanings, but this does not make them innocent. Boundaries have real material consequences (Barad, 1996, p. 187).

2.7.4. Posthumanism and agency

Agential realism is a posthumanist theory which means that dichotomies such as human and nonhuman are not taken for granted and that an anthropocentric worldview, where humans are the center of attention and analysis, is avoided. Barad (2007) points out that practices and phenomena, as ongoing intra-activities of the world, do not have to involve humans at all. For instance, Barad’s (2007) understanding of discursive practices is post-humanist since this is not considered a human phenomenon due to that the distinction between human and nonhuman is not given. Instead, her definition of discursive practices focus on the material (re)configurings through which boundaries and meaning are

becoming determined. Hence, this has to do with material intra-activity of which ‘humans’ can be a part or not. In summary, posthumanism entails focus on practices in which boundaries such as ‘human’ and ‘nonhuman’ are enacted. This also means that phenomena are not brought into being by “the perception of the human mind” (Barad, 2007, p. 129) or the result of human measuring practices. We do not enact entities by assembling or choosing apparatuses to produce desired phenomena or to satisfy certain knowledge projects:

Saying something is so does not make it so. Likewise, making and using particular instruments in a lab do not produce whatever results are desired. (Barad, 2007, p. 211)

Instead, we are *part of* the ongoing (re)configurings of the world:

“We humans” don’t make it [phenomenon] so, not by dint of our own will, and not on our own. But through our advances, we participate in bringing forth the world in its specificity, including ourselves. (Barad, 2007, p. 353)

The posthumanist stance also calls for a reconceptualization of agency. Here, agency and change are not simply attributed to humans, culture and social factors, making nature and matter passive. In agential realism, agency is not considered a ‘thing’, an attribute or property of someone or something – a subject or an object cannot have agency. Instead, agency is described as action; “agency is ‘doing’ or ‘being’ in its intra-activity” (Barad, 2007, p. 178). It is a capacity to make differences which is coming into being through certain relations (Orlikowski, 2007; Orlikowski & Scott, 2008). This means that agency is “relational, emergent, and shifting” (Orlikowski, 2007, p. 1438). Agency is congealed in the intra-activity of material-discursive practices, e.g. through the various intra-actions which are continuously (re)configuring. Hence, agency is dynamic in the same way as (re)configurings are. Changes are brought forth by variations in intra-actions, hence, agency lies in the intra-activity.

The previous sections have presented the main concepts and ideas of agential realism. These are summarized in Box 2.1. The next section provides examples of how agential realism has been applied in IS research.

2.7.5. Applications of agential realism in IS research

As proponents of strong sociomateriality, Orlikowski and Scott have contributed with empirical studies using agential realism. As described above, they have studied the enactment of anonymity through social media (Scott & Orlikowski, 2014). They also use agential realism to study the material-discursive practices of service innovation. In their study of a social media platform in the hospitality sector, they show how this service is an entanglement of travelers, hotels, reviews, ratings, algorithms, ‘the crowd’ and so on, which then shape actions of readers, hotels and service providers (Orlikowski & Scott, 2015). Another example of a study applying agential realism is Sefyrin (2010). In her thesis, she uses agential realism to analyze and explore gender, power and knowledge in participatory IT design. She shows how women were both centralized and marginalized through the practices of IT design, the production of boundaries, knowledge and responsibility.

Box 2.1. Summary of agential realism

Below, the main points of agential realism are summarized:

- Agential realism builds on a relational ontology which entails that the world consists of relations without relata. Synonyms to relations are intra-actions, entanglements, phenomena, relationalities, (re)configurations, (re)configurings, and (re)articulations.
- Relations are (re)configuring continuously in practice. This performativity entails that stability and structure are ongoing accomplishments and, hence, the world is dynamic and constantly emerging.
- Apparatuses are material-discursive and boundary-making practices, they are productive of e.g. subjects and objects, matter and meaning. Synonyms to apparatuses are material-discursive practices, material practices, discursive practices, material articulations, physical arrangements, and concepts.
- Apparatuses produce boundaries by inclusion and exclusion, i.e. some boundaries become determinate which also renders others indeterminate.
- Apparatuses are part of phenomena, i.e. apparatuses and 'entities' intra-act. This entails that changes in the apparatus also changes the phenomenon.
- Apparatuses are enacted by other material-discursive practices. This entails that they are open-ended and that different material-discursive practices are entangled and help constitute each other.
- Matter and meaning are defined and become determinate in material-discursive practices. They are constituted by intra-actions – specific physical arrangements. Matter and meaning are mutually articulated, i.e. they are always both material and discursive.
- Agency is to intra-actively become and, thus, make a difference in the world. Agency is dynamic and emergent.

In terms of research focusing on innovative IT design and applying agential realism, studies are scarce. Bjørn and Østerlund (2014) draw on Barad (2007) and Suchman (2007) in two ethnographic studies of design processes in emergency departments. They propose the term sociomaterial-design to account for sociomaterial practices and boundaries in design. In their study, they show how emergency departments are full of artifacts and healthcare practitioners that co-constitute each other and are configured in practice. They also point to the complexities of 'breaking up' these configurations in (re)design projects and how this leads to undesired and unforeseen effects. For instance, healthcare practitioners were unwilling to break up certain configurations and the negotiations about emergency department artifacts also lead to debate concerning power and responsibilities among doctors and nurses. Hence, breaking up configurations create ripple effects throughout the entanglement. One of their main points is that sociomaterial-design can enable designers to study

entanglements to find ‘spaces for design’ which are more open to reconfiguration. Their studies are inspiring first steps toward an agential realist understanding of why some IT designs are difficult to change to more innovative ones and how this understanding can help in overcoming the difficulties of designing innovative IT, when this is considered an appropriate endeavor. My hope with this thesis is to contribute to this line of research and understanding.

2.7.6. Advantages and disadvantages of agential realism

This section discusses the essential questions: What are the pros and cons of using agential realism in the IS field in general and when studying why it is difficult to design innovative IT in particular? One of the main advantages of applying agential realism in IS research is that it provides the possibility to explore how the social and the technological are inextricably constituted. Thus, it can provide a lens in which IS researchers do not focus too much on either the social or technological aspects of IS phenomena, since this has been criticized (Orlikowski, 2007), but instead study how IT, people, organizations etc. come into being in entanglement and are part of defining and constituting each other. In terms of studying why it is difficult to design innovative IT, agential realism provides a theoretical lens that can shed new light on how the agencies for changing IT design can be understood. Agential realism helps to shift focus from individual designers to understanding how possibilities and impossibilities of innovative IT design emerge in intra-activity, including the materiality and discursivity of IT, knowledge, designers and users etc.

However, agential realism and sociomateriality is a rather hot debate in the IS field and not without their critics. For instance, although IS scholars have called for theories conceptualizing the IT artifact, one of the main points of criticism towards agential realism is that it is too theoretical and philosophical (Leonardi, 2013). Kautz and Jensen (2013, p. 16) also point out that agential realism introduces even more “academic jargon monoxide”. To answer this critique, we can start by scrutinizing some underlying assumptions.

Language plays a vital role in understanding the world as divided into separate and pre-defined things. In this sense, language helps to reproduce representationalist assumptions, i.e. that people and things have inherent properties (Cecez-Kecmanovic et al., 2014). These assumptions are embedded and taken for granted in our language, which leads to that we, through our language, continuously maintain the separation and duality of people and IT. This is a challenge in IS research that aims to investigate how IT, people and organizations are emerging together. As the duality is entrenched in our language and everyday understanding of the world, we need ways to “reveal the taken-for-granted” (Orlikowski & Scott, 2008, p. 465). Here, agential realism plays an important part as it can be used to defamiliarize oneself from everyday notions and assumptions of the world to make room for new insights. For instance, Gregor (2006) argues that IS researchers use theory to explain how, why, when and where phenomena occur, to create a better understanding of IS phenomena:

These theories often have an emphasis on showing others how the world may be viewed in a certain way, with the aim of bringing about an *altered* understanding of how things are or why they are as they are. (Gregor, 2006, p. 624, emphasis added)

Accordingly, agential realism is used in this thesis to provide an altered understanding of why it is difficult to design innovative IT. By building on the unconventional set of assumptions in agential realism, it can be used to defamiliarize oneself, reveal the taken-for-granted and, hence, create new understandings of this IS phenomenon.

Furthermore, Orlikowski (2007) and Kautz and Jensen (2013) argue that IS research can gain analytical insight by giving up the separation between the social and material. By developing a vocabulary that enables us to think and talk about the social and material as inseparable (Orlikowski & Scott, 2008), we can exceed this duality and understand how they are continuously performed and coming into being (Orlikowski, 2007). Accordingly, the stream of sociomaterial IS research, which includes agential realism, can be seen as an attempt to develop such a vocabulary and ways of thinking that transcends conventional conceptions of the social and material (Orlikowski, 2007; Orlikowski & Scott, 2008):

By providing an ontological position and theoretical apparatus for examining entanglement and enactment, agential realism offers conceptual and analytical traction for making sense of the world and its possibilities in new ways. (Scott & Orlikowski, 2013, p. 78)

In this sense, agential realism follows the IS tradition of trying to take both social and technological aspects of IS phenomena into consideration. Agential realism allows us to take this one step further by enabling IS researchers to study the *inseparability* of the social and material without resorting to dualistic thinking (Orlikowski, 2007; Orlikowski & Scott, 2008). It should, however, be pointed out that also agential realist and sociomaterial vocabulary struggles with dualistic vocabulary:

Part of the difficulty in discussing the new perspective is that our language makes it difficult to express indissolubility. We are used to dividing, separating, and distinguishing. Thus, even terms such as “mutual constitution,” “entanglement,” “assemblage,” and “relationality” allude to separateness, even as they try to move beyond it. (Orlikowski & Scott, 2008, p. 468)

This may partly explain Barad’s (2007) use of many different synonyms and hyphenating to join again what language has divided, e.g. ‘material-discursive’. Thus, these concepts are to help us move beyond representationalist assumptions.

Another critique of agential realism is that the theory’s complex vocabulary increases the gap between researchers and practitioners (Kautz & Jensen, 2013). This critique is valid and puts pressure on researchers to communicate results clearly and transparently, ‘translating’ research into ‘everyday’ language and practical implications. However, Kautz and Jensen (2013) also acknowledge the need for specific vocabularies in academic work to investigate complex phenomena. To conclude, agential realism is highly theoretical, philosophical and entails a complex vocabulary but this is justified since these are tools that help us defamiliarize ourselves from conventional assumptions and, thereby, understand the world and IS phenomena in new ways.

Methodological challenges

Much of the critique towards agential realism has to do with methodological matters. Kautz and Jensen (2013) pose questions about how to gather and present empirical data, e.g. how to include ‘voices’ of the material. Furthermore, agential realist analyses in the IS field have been accused of applying the theories only partially or being cursory (Kautz & Jensen, 2013). Hence, it has been questioned whether the complex theoretical vocabulary is useful when analyzing IS phenomena (Kautz & Jensen, 2012). This critique is met by Scott and Orlikowski (2013) who argue that sociomateriality and the application of agential realism is in its infancy, that researchers have just started to interpret and adopt these theories in their studies and that a lot of work remains to be done. M. Jones (2014) adds that implications of sociomateriality and agential realism need to be empirically explored. As mentioned in Chapter 1, these are also prospective knowledge contributions of the thesis, i.e. to make an empirical and a methodological contribution by applying agential realism in IS research.

These sections have shown that there are both advantages and disadvantages of agential realism but that, overall, the theory contributes to the theoretical plurality in the IS field. The discussion above also indicates that agential realism is promising when aiming to develop altered understandings of IS phenomena. All theories build on assumptions, pose different questions, take some things as given and have blind-spots, but with a variety of approaches in the IS field, we can gain both a broader and a deeper understanding of IS phenomena. To conclude, sociomateriality in general, and agential realism in particular, do not make other theories or perspectives obsolete but adds to the plurality of the field.

This chapter has accounted for the theoretical foundation of the thesis, including previous research and core concepts about innovative IT design, the difficulties of innovation and how these difficulties can be overcome. It has also presented agential realism, which is the theoretical lens used in this thesis. The previous research presented in this chapter, and agential realism in particular, will be employed as analytical tools to help understand and explain the empirical material of the thesis and to answer the research question. Agential realism is also a recurring topic in the next chapter as the theoretical lens has methodological implication. These matters are elaborated in the following chapter which presents the research approach of the thesis.

3. Research approach

This chapter accounts for the research approach of the thesis. The initial sections describe and discuss methodological choices including philosophical assumptions, research method, data generation techniques, analytical approaches and how the quality of the research can be evaluated. The final sections provide a detailed account of the research process.

3.1. Philosophical assumptions

Today, there is a wide array of research approaches and methodologies used and accepted by researchers in the IS field (Venkatesh et al., 2013). This methodological diversity has developed over time and has been subject to debate (see for instance Benbasat & Weber, 1996; Robey, 1996). IS research approaches now range from quantitative to qualitative approaches drawing on various philosophical assumptions, such as positivism, interpretivism and critical studies including sociomaterial and performative perspectives (Cecez-Kecmanovic et al., 2014; Orlikowski & Baroudi, 1991; Orlikowski & Scott, 2008). As mentioned in the previous chapters, this thesis builds on agential realist assumptions of the world. However, during the process of conducting this research, my ontological assumptions have shifted. In the early stages of the research, I was drawing on interpretivist assumptions about the world, using qualitative methods that are recognized in this research tradition. However, as a combination of readings on sociomateriality and my analysis of the empirical data (elaborated in section 3.6.4.), I started to search for ways to study material aspects and not only people's interpretations. This led me to apply an agential realist perspective. Accordingly, many methodological decisions were made before this ontological shift. This does not make the empirical data less valuable, but it is in place to comment on the methodology from an agential realist perspective.

3.1.1. An agential realist perspective

From an agential realist point of view, methods are material-discursive practices. This means that methods, ranging from quantitative measurements to qualitative interpretations, “produce differences that matter—they are boundary-making practices that are formative of matter and meaning, productive of, and part of, the phenomena produced” (Barad, 2007, p. 146). Hence, they are not innocent tools that ‘capture’ reality. Boundaries produced in research are enacted by a range of material-discursive practices including researchers, respondents, colleagues, observations, interviews, recording devices, transcripts, theories, previous research, research journals, books, seminars, writing and reading, etc. (Nordstrom, 2015). These intra-acting practices produce the research results and are also part of them.

This has implications for how to understand the role of the researcher. Here, the researcher is part of the research apparatus and, thus, enacts boundaries in the research. Or as Scott and Orlikowski (2014, p. 880) put it; “we too make agential cuts in our (research) practice, producing specific distinctions, boundaries, and properties”. As researchers, we cannot depict the world as *separate* from our own interpretive apparatuses (Barad, 2007). We cannot

study phenomena from a distance, representing things in the world. However, although the researcher plays an important role in research, the researcher is not the center of creating meaning and knowledge but *is part* of ongoing intra-actions of respondents, theories, recording devices and so on, which cannot be teased apart. This performative understanding of methodology and the role of the researcher also entail that ontology and epistemology cannot be separated. Barad (2007, p. 184) argues that researchers “are not outside observers of the world”. We cannot study the world from a distance – we are part of the world:

Practices of knowing and being are not isolable; they are mutually implicated. We don’t obtain knowledge by standing outside the world; we know because we are of the world. (Barad, 2007, p. 185)

Since ontology and epistemology cannot be separated, Barad (2007, p. 185) suggests the term *ontoeπισtemology*, i.e. “the study of practices of knowing in being”. This means that knowing entails specific practices which enact the world in specific ways.

That researchers and research practices are part of producing the world in specific ways also have ethical implications. This entails that we are “responsible not only for the knowledge that we seek but, in part, for what exists” (Barad, 2007, p. 207). That is, we must be accountable for the specific enactments – inclusions and exclusions – performed in our practices. Barad (2007) emphasizes that researchers have to account for the apparatuses that produce research phenomena since different apparatuses produce different configurations of the world. To conclude, since the researcher and her methods produce and co-constitute the research results, the aim of this chapter is to provide an account, as transparent as possible, of the practices which produce the results of this thesis.

Language and assumptions as apparatuses

As mentioned in the previous chapter, dualistic assumptions are embedded in our language. This has methodological implications. Orlikowski and Scott (2008) argue that assumptions held by researchers influence what researchers do and focus on, what they perceive as salient aspects or not, how they generate and analyze data, and in the end also what they find. By assuming the distinction and inherent properties of ‘entities’, this division is reproduced throughout the research:

This presumption of separation is then inscribed in the priorities of the study and, most importantly, in its analytical gaze, producing strategies of data gathering and analysis that are necessarily split between two categories: the technologies (artifacts, techniques, systems, media) and the social (meaning, activities, contexts, outcomes). (Orlikowski & Scott, 2008, p. 463)

This entails that the findings will also build on these assumptions, making other understandings of the social and material impossible:

The language and assumptions of separation thus lead conceptually and methodologically to a realm of possible findings that are already configured. ... As a result, we lose the possibility of seeing the technical and social as inextricably fused. (Orlikowski & Scott, 2008, p. 463)

Accordingly, language is both necessary in our research but also a challenge since it separates and enacts specific understandings of the world. By drawing on assumptions

other than representationalism, this enables different boundaries to be enacted in research, leading to other understandings of the world. Barad's (2007) agential realism provides tools to help us speak of the material and the social "in the same register" (Orlikowski, 2007, p. 1437), e.g. through concepts such material-discursive. This is a step on the way of studying the world as performative and relational. In this sense, the vocabulary and ideas of agential realism are prominent apparatuses in this thesis and in the enactment of the research results.

3.2. Research method

Research method can be defined as a strategy of inquiry, i.e. "a way of finding empirical data about the world" (Myers, 2013, p. 25). Examples of research methods include case study research, ethnography and action research (Myers, 2013). One of the most widely used qualitative research approach in the IS field is case study research (Darke et al., 1998), which also is the research method used in this thesis.

3.2.1. Case study research

A case study can be defined as an empirical inquiry where a contemporary phenomenon is investigated in depth in its real-world context (Yin, 2013). A case can be "a single example (of a social process, organisation or collectivity) seen as a social unit in its own right and as a holistic entity" (Payne & Payne, 2004, p. 31). In this thesis, the case is an example of an attempt to design innovative IT in a healthcare context (presented in Chapter 4).

Case studies are advantageous for several reasons. One of the major strengths of the method is the opportunity to study phenomena in a real-world context. This is especially important when the studied phenomenon is considered inseparable from its context. For instance, Benbasat et al. (1987) and Walsham (1995) advocate that phenomena such as IS development, implementation and usage should be studied in a real-world context where social and organizational issues are taken into account. Similarly, Cavaye (1996, p. 239) argues that "the capturing of context is always important when discussing people-related and organisational phenomena and that, therefore, case research is always an appropriate research strategy in IS". Also Darke et al. (1998, p. 273) argue that case studies are "well suited to understanding the interactions between information technology-related innovations and organizational contexts". Hence, a case study is suitable to study why it is difficult to design innovative IT since it enables an in-depth and on site exploration of this topic.

Case studies are also advantageous when studying both social and material aspects of phenomena. Cecez-Kecmanovic et al. (2014) suggest that researchers need to 'dwell in' the sociomaterial world to be able to study performativity and practices in which both humans and nonhumans are included. In this sense, case study research is a suitable method when applying an agential realist perspective.

Furthermore, case studies can include one single case or multiple cases (Cavaye, 1996). Studying a single case enables the researcher to produce rich descriptions and in-depth investigations (Darke et al., 1998), whereas multiple cases limit the level of detail that can

be generated. In-depth case studies include “frequent visits to the field site over an extended period of time” (Walsham, 1995, p. 74). In the field, empirical data are generated in different ways, through e.g. interviews, documents, participant observations and studies of artifacts (Yin, 2013). By visiting the field frequently and studying the case using different data generation techniques, a large number of aspects or variables can be studied. These aspects can emerge during the case study and do not have to be predefined, i.e. case studies can be more or less structured (Cavaye, 1996). Less structured case studies enable a more exploratory approach while also being explanatory (Myers, 2013). Thus, researchers can explore and describe *how* something is and explain *why* it is like this. Although studying one case is sometimes criticized for being idiosyncratic, the possibility to conduct an in-depth and detailed case study with a single case was preferred above several cases. The aim of this thesis is to explore and explain why it is difficult to design innovative IT and, thus, a single case was considered appropriate since it enables an in-depth exploratory approach with rich and detailed descriptions. This is also advantageous when applying an agential realist perspective. For instance, Barad (2007) points out that researchers should be highly attentive to details since these make a difference in what boundaries are produced or not.

There are alternative research methods with similar advantages as case study research. Action research can also provide in-depth explorations but since this thesis does not aim to solve practical problems, this method was not considered appropriate. Also ethnography was ruled out, mainly because it would mean to spend many months immersing myself in the daily lives of the participants (Myers, 2013). However, the case study presented in this thesis is similar to ethnography in the sense that its main empirical data is generated through participant observation.

A disadvantage of case study research is that the generation and analysis of empirical data often are time consuming. When generating many different kinds of data, which adds to the richness of the empirical material, the downside is an imminent risk of data overload. A great volume of data can lead to difficulties when setting out to analyze it (Cavaye, 1996). To cope with this disadvantage, it is valuable for the researcher to continually organize the empirical material as this enables an overview and facilitates analysis (Darke et al., 1998). Case study research has also been criticized for using qualitative data analysis methods that are not well defined and established, adding to the impression that case study research is not rigorous (Darke et al., 1998). This critique stems from a comparison between quantitative and qualitative data analysis methods where the former is typically more governed by rules and standard procedures, than the latter. A response to this critique is to develop and clearly present a data analysis strategy that specifies what should be analyzed and why (Darke et al., 1998). The analytical approach of the thesis is elaborated in section 3.4.

To conclude, case study research comes with advantages and disadvantages. Many of the strengths of this approach are at the expense of its limitations; to gain a rich picture of the case is at the cost of risking data overload and a tedious analysis process. In my methodological considerations, I have favored some strengths over the weaknesses to be able to study and answer the research question.

3.3. Data generation techniques

As mentioned above, different data generation techniques are used in case study research (Myers, 2013). The main technique in this thesis is participant observation, which is complemented by semi-structured interviews. The generated data have been documented by several means; field notes, video and audio recordings, photography and documents. In the following sections, participant observation is described, discussed and motivated including how the observations have been documented. This is followed by an account of the semi-structured interviews.

3.3.1. Participant observation

Participant observation is a data generation technique that involves observing and interacting with people in their ‘normal’ context (Myers, 2013). This technique is often used over an extended period by watching, listening and asking questions as people go about their everyday lives (Payne & Payne, 2004). Accordingly, the researcher is more or less involved in what is happening, to achieve an understanding of it (Myers, 2013).

Participant observation is advantageous when trying to understand the context of phenomena as it entails that researchers engage and interact with actors and their contexts. The technique is considered suitable for taking multiple perspectives into account in IS design processes, enabling a rich and nuanced picture (Nandhakumar & Jones, 1997). Furthermore, IS researchers often have to account for the complexities of technological and social systems and how these relate to each other (Lee, 2001). Accordingly, data generation techniques that can encompass such complexity is needed. Brown (2014) advocates participant observation for studying complex processes over time, e.g. to understand design processes. She argues that:

A key aim [with participant observation] is to understand how the subject group interacts with each other and with the *specific social and cultural context of the time and place* of the research, when dealing with the phenomenon under investigation. (Brown, 2014, p. 171, emphasis added)

That is, participant observation is an appropriate technique when studying the complexities of entanglements where the technological and social are enacted in specific contexts. Participant observation also allows researchers to observe and even engage with IT in use, during development or implementation in a specific context (Brown, 2014). Hence, the technique enables researchers to study both social processes *and* focus on IT artifacts. Unlike interviews and similar techniques which focus on language, participant observation also allows researchers to study practices or ‘doings’. This includes what people are doing and not just what they are saying (Myers, 1999), but also doings in an agential realist sense – to study intra-actions and enactments. Accordingly, participant observation is a suitable technique when exploring material-discursive practices. Furthermore, participant observation resonates well with Barad’s (2007) argument that researchers are *part* of the world and that knowing does not come from watching at a distance but by engaging with and as part of

the world. Thus, participant observation is in line with this idea since the researcher is not portrayed as detached in this data generation technique.

When conducting participant observations, the researcher is faced with choices about how to carry out the observations. For instance, observations can be overt or covert, meaning that the participants may be aware of that they are being studied by a researcher (overt) or that they do not have knowledge of this (covert) (Jorgensen, 1989). The participant observations in this study have been overt, which means that all participants have been aware and approved of that I was participating as a researcher and that my observations would be used for research. According to Jorgensen (1989), an overt strategy is preferred over a covert since it raises less ethical concerns.

The researcher must also choose how much she will participate during the observations. The level of participation in observations can be described as a continuum ranging from complete outsider to complete insider (Jorgensen, 1989). The former entails that the researcher observes people from an outside perspective without participating in the events. The latter entails that the researcher both observes and participates by interacting with people in order to gain an insider perspective. This means that the researcher may be more of an observer during some events and more of a participant in other situations (Myers, 2013). This is especially important for IS researchers who are studying IT artifacts – to actually use the artifact under investigation (Brown, 2014). By combining data of what the participants say and do with first-hand experiences, a richer and more nuanced picture, drawing on multiple viewpoints and sources, is gained (Jorgensen, 1989). During the participant observations conducted in this thesis, I have altered between passive observations and more active participation to both learn from watching others but also to gain first-hand experience of IT artifacts in the case (elaborated in section 3.6. where I describe the research process).

However, as with all methods, there are also disadvantages of participant observation, many which are similar to those of case study research, which were discussed above. A clear limitation with this in-depth data generation technique is that it is difficult to study more than one rather small case at a time. However, Esterberg (2002) argues that small-scale sites are suitable for participant observation. This enables the depth and richness in data that is also the strength of the technique. Another disadvantage of participant observation is that it tends to take a lot of time. Since I have not ‘gone native’ (Myers, 1999) as participant observers in ethnographies sometimes do, this disadvantage has not been salient. Instead of spending long periods in the field, I have visited meetings and workshops in the case (elaborated in sections 3.6.2. and 3.6.3.). Other critique towards participant observation is that it can lead to narrow topics, purely descriptive accounts and limited analyses and theoretical contributions (Myers, 2013). These pitfalls have been avoided by posing a rather general research question and by applying a theoretical lens that can contribute to a more explanatory contribution rather than mere description. To conclude, participant observation is considered an appropriate data generation technique that helps to answer the thesis’ research question as it enables the study of IT as sociomaterial, including aspects such as

materiality, practices, complexity, context and social processes. These are all considered relevant aspects when aiming to explain why it is difficult to design innovative IT.

Documentation of participant observations

When conducting participant observations, researchers need ways to document what they are observing – usually by taking field notes. These can be complemented by various kinds of recording equipment, e.g. cameras and video and audio recorders, as this enables more detailed and rich data than what is possible in field notes (Myers, 2013; Payne & Payne, 2004). This study makes use of both field notes, video and audio recordings, photography and documents to provide a rich account. These are described in the following paragraphs.

Field notes. During participant observation, it is custom that the researcher takes field notes. This includes writing down what she is seeing and hearing but also what she is thinking and feeling in the observed situation (Myers, 2013), e.g. impressions, potential leads (Payne & Payne, 2004), hunches and analytical comments (Jorgensen, 1989). Taking and reviewing field notes iteratively play a crucial role in the process of (re)defining phenomena and focusing the observations (Jorgensen, 1989), thus, refining the research question and focus. This has also been the case in this work. The process of observing and defining the research question is elaborated in section 3.6.1. From an agential realist perspective, taking field notes is an important practice or apparatus in producing the research. That is, taking field notes entails an active process where the researcher interprets and makes sense of what she judges to be important and interesting or not, in the case (Esterberg, 2002).

A disadvantage of taking field notes is the challenge to both observe, participate and write more or less simultaneously. Even if the researcher writes up the field notes in close relation to the observation to get as many details as possible, as suggested by Myers (2013), there is a limitation to how detailed the notes can be. Thus, field notes are often accompanied by other documentation techniques such as video and audio recording, as is the case in this study. The latter techniques result in more detailed documentations than field notes, whereas the observations enable a contextual understanding of the activities taking place in the recordings (Díaz Andrade et al., 2015; Heath et al., 2010). In this sense, these techniques complement each other.

Video and audio recording. By recording observations, researchers may study complex phenomena in detail – watching and re-watching the videos with e.g. different analytical lenses or foci. Furthermore, both audio and video recordings can be transcribed and analyzed. The recordings and transcripts can either be used for microanalyses or function as an ‘external memory’ for the researcher or as detailed field notes (Corsaro, 1982; Heath et al., 2010). In this thesis, audio and video recordings have both been transcribed and functioned as detailed field notes together with the actual recordings. One of the advantages of this approach is that observations and video recordings do not center around language but are multimodal (Corsaro, 1982). This includes “talk, visible conduct, and the use of

tools, technologies, objects and artefacts” (Heath et al., 2010, pp. 5–6). According to Heath et al. (2010), video recording can counter the linguistic turn which Barad (2007) criticizes:

“The challenge then is to prioritise the material, to give ordinary objects and artefacts the analytic attention normally afforded to the major topics addressed by the social sciences. ... Video-based studies can provide the practical and methodological resources through which we can begin to counter the ‘linguistic turn’ and to take seriously the ways in which social action is produced as intelligible by virtue of the interplay of the spoken, the visible and the material” (Heath et al., 2010, p. 146).

This is a promising methodological point for taking the IT artifact seriously. Heath et al. (2010, p. 93) conclude that “video-based studies do lend themselves to the qualitative study of technology in action” including the design, development and implementation of new technologies. Also, as mentioned above, this type of data and focus is suitable when applying an agential realist lens since the multimodality facilitates analyses of enactments and material-discursive practices. Accordingly, I have used the benefits of video recording to generate rich empirical material which enable a fruitful agential realist analysis, i.e. to pay analytical attention to IT as a sociomaterial entanglement.

As with qualitative data in general, a downside of video and audio recordings is that data can be difficult to analyze because of the amount of details – what should the researcher focus on? On the other hand, recordings can be watched, listened to and analyzed repeatedly with different analytical lenses (Heath et al., 2010). For instance, by watching in slow motion or zooming in on different aspects, details that are easily missed when at the field site can become apparent when re-watching the material (Díaz Andrade et al., 2015; Heath et al., 2010). Accordingly, the level of detail in the data is both a strength and a challenge. To cope with the amount of detail in the empirical material, I have used the theoretical lens to delimit what should be highlighted in the analysis or not. This is elaborated in section 3.4.2. Another challenge with video recordings is to present the data in a comprehensible way for readers. This is commented on below where I discuss photography.

Moreover, video and audio recordings are often described as obtrusive and the equipment may affect participants and their behavior. This calls for the researcher to be as unobtrusive as possible when using recording equipment. However, even though participants are aware of being recorded, this does not have to compromise the quality of the data. Heath et al. (2010) argue that when people engage in their activities, they are focused on accomplishing their work tasks rather than on being observed or recorded. The authors also argue that it is very difficult for people to fake the details of their conduct for longer periods. On the contrary, the recording equipment is often normalized, forgotten or taken for granted after a brief period (Jorgensen, 1989). During my observations and recordings, participants sometimes commented on the recording equipment in the beginning or end of the meetings or workshops. However, when they engaged in discussions and their work tasks, they did not focus on me or my equipment. Yet, since recording is obtrusive, it is important that this is carried out in an ethically sound way. The Swedish Research Council (2011, p. 43) argues that “[i]t is important that the filming be done in a respectful and responsible way.

The individual's integrity should be respected". For instance, the researcher needs informed consent from every participant being video recorded. This is elaborated in section 3.5.2.

To conclude, video and audio recordings come with many advantages when studying IT and people and when applying agential realism. As with all methods, they also have limitations but most of these can be compensated for, as discussed above. Hence, these data generation techniques are considered valuable when studying why it is difficult to design innovative IT.

Photography. In this study, photography has mainly been used to document artifacts and settings. These artifacts and contexts have also been studied through participant observations and video recording, but photography is advantageous when wanting to communicate these visual aspects to the reader (Díaz Andrade et al., 2015). Hence, I have used photos to illustrate what cannot be communicated using only words, hopefully giving the reader a more vivid view of the case.

Documents. Documents of various kinds can be used to complement observations and other data generation techniques as they help to gain a richer picture of the context and the events of a case, e.g. as background information (Myers, 2013). In this thesis, documents which were used by the participants in the case have been used to better understand what the participants talk about, e.g. lists of requirements. Other documents which related to the case have also been used to understand the context of the case. Working with documents may not be straightforward since the researcher needs to know how to interpret them. This can be facilitated by having access to the original authors (Myers, 2013). In this way, the researcher can discuss interpretations with the participants and sometimes even the authors of the documents. For instance, during my observations, I asked questions about the requirement specification document written by the participants, to get clarifications. This helped me to better understand the participants' discussions about the requirements.

As a concluding reflection, it can be pointed out that the combination of different types of data from the participant observations are considered a strength – together they add to a richer picture of the case (Myers, 2013).

3.3.2. Semi-structured interviews

As mentioned above, the participant observations were accompanied by qualitative semi-structured interviews. The semi-structured interview is a widely used method in qualitative IS research (Myers & Newman, 2007). It entails many advantages such as exploring certain topics openly while being responsive to what respondents bring up in terms of e.g. experiences, opinions or feelings (Esterberg, 2002). This gives the data generation some structure in terms of pre-formulated questions or topics whereas it also entails flexibility as respondents may diverge from the topics and the researcher may ask improvised follow-up questions (Myers, 2013). Interviewing is also "an especially useful strategy for discerning different viewpoints held by insiders" (Jorgensen, 1989, p. 88). In this sense, participant observation and semi-structured interviews are a fruitful combination as it allows researchers to both ask questions about topics introduced by the participants (e.g. when

topics naturally occur during observations), but also to introduce topics of their own. e.g. in interviews (Jorgensen, 1989). For instance, in the interviews in this study, I could ask the respondents to reflect more on the events in the case without being obtrusive during meetings which I observed. Interviews were more suitable for questions such as “What does innovation mean to you?” which would have interrupted the meetings.

A usual critique of semi-structured interviews is that interviewer and respondent are complete strangers and that interviews are intrusive. This is argued to inhibit trust and disclosure (Myers & Newman, 2007). However, by combining interviews with participant observation, this disadvantage can be reduced. For instance, Jorgensen (1989) advocates that formal interviews should be conducted during the later stages of participant observations. This makes it easier to establish rapport with the respondents as researcher and respondents usually have a more personal relationship (Esterberg, 2002; Jorgensen, 1989). By conducting interviews during the later stages, this also gives the researcher an idea of what questions are relevant to ask. The interviews in this study were conducted after a period of observations and, in line with the argument above, they differed from those of a case study using only interviews.

Another usual critique of interviews is that interviews create opinions and attitudes (Myers & Newman, 2007). That is, respondents reflect on topics they had not thought about before and thereby ‘create opinions’ during the interview. This is valid critique, but from an agential realist perspective, the interview is an apparatus that is part of producing the world in specific ways – just as any other method. Accordingly, interviews do not capture what is already there but produce boundaries. For instance, Mazzei (2013) points out that interview data comes from the intra-actions of researcher-data-participants-theory-analysis. That is, the words and experiences of an respondent do not come from an individual person – there are no pre-existing subjects (Barad, 2007). Instead, interview data are performed by several material-discursive practices, e.g. the research practice, interview practice, professional practices, discourses, theories, previous data and analysis and so on (Mazzei, 2013). Accordingly, the respondent, interviewer and interview data are performed in practice. Or put differently, interviews do not happen *between* subjects. Instead, Kuntz and Presnall (2012) draw on Barad and suggest the term *intraview* to denote the many material-discursive practices which are intra-actively forming matter and meaning in interviews. What is important here is to acknowledge the interview as an apparatus and to account for how this apparatus is part of producing the world. As mentioned in section 3.1.1., the aim of this chapter is to provide an account of the various practices that produce the empirical data and research results of this thesis. Hence, the interviews are elaborated in section 3.6.2.

3.4. Analytical approaches

In qualitative research, analysis is rarely a separate phase from that of generation of empirical data (Myers, 2013). Instead, different research phases are iterative and affect each other, e.g. defining the research topic and question, generating empirical data and analyzing:

This process of observing, analyzing, refocusing, and observing again may be repeated over and over again as you explore and refine emerging problems and questions of inquiry. (Jorgensen, 1989, p. 84)

Myers (2013) argues that analyses can be performed ‘bottom up’ (inductively) or ‘top down’ (deductively). The former is an exploratory approach where categories or concepts emerge from the empirical material, whereas the latter entails that theories and concepts from previous research are applied to understand the material. Researchers can iterate between the two approaches, positioning themselves somewhere on the continuum between induction and deduction (Myers, 2013). In this thesis, two approaches for analysis have been used which I term ‘data-driven analysis’ (cf. ‘bottom up’) and ‘theory-driven analysis’ (cf. ‘top-down’). These are described in the following sections.

3.4.1. Data-driven analysis

As mentioned above, qualitative research tend to result in vast empirical material. This calls for sorting and organizing the data in some way to make sense of it. This is often done through *coding* the data, i.e. to attach codes, tags or labels to ‘chunks’ of data (Myers, 2013). This helps organize the data into themes or categories which enable researchers to get a better overview of the material (Myers, 2013; Ryan & Bernard, 2003). Coding is iterative and often conducted several times through recoding with different foci each time:

Efforts to code data will lead to sorting, sifting, organizing, and reorganizing these materials, usually into larger units and components. ... Is a pattern discernable? (Jorgensen, 1989, p. 110)

For instance, open coding is often used in the early phases of analysis as it is descriptive and helps summarize the material (Myers, 2013). Coding of the empirical data may also focus on repetitions, similarities and differences or missing data. This highlights that there is no single ‘correct’ way to code or thematize data, but that the empirical material can be seen and understood in numerous ways (Ryan & Bernard, 2003). Coding has been used iteratively in the analysis of the empirical material in this thesis to organize and get an overview of the data.

An advantage of starting the analysis with open coding and a ‘bottom up’ approach is that, by avoiding a specific theoretical lens, new ideas and surprising connections can be made. However, preconceptions and prior knowledge of the researcher cannot be avoided completely (Van de Ven, 2007). That is, coding is done through researchers’ judgments and, thus, this requires that researchers make these judgments explicit and clear so that readers can review if they find the conclusions convincing (Ryan & Bernard, 2003). This has led me to describe my process of analysis as transparently as possible in section 3.6.4.

3.4.2. Theory-driven analysis

Even though data-driven analyses have the advantages of avoiding theoretical influencing and only finding what the theory ascribes, theory and previous research are still important tools for identifying relevant research questions and explaining what the researchers find in their empirical material (Jorgensen, 1989; Ryan & Bernard, 2003). Due to this, a theory-driven analysis has also been conducted in this thesis.

Jorgensen (1989, p. 16) argues that “[t]heories provide a perspective, a way of seeing, or an interpretation aimed at understanding some phenomenon”. Similarly, Gregor (2006) argues that theories for explaining (such as structuration theory, ANT and agential realism) can help explain what, how and why something is as it is. This is not done through positivistic, testable predictions but theory is used as a ‘surprise machine’ or ‘sensitizing device’ to understand and explain the world in new and altered ways (Gregor, 2006; Klein & Myers, 1999). That is, by applying other assumptions than what have been used before, theory can help detach ourselves from conventional notions to enable other understandings (Gregor, 2006). As mentioned in the previous chapters, agential realism is used in this thesis to help explain and understand the difficulties of designing innovative IT. By drawing on the unconventional assumptions in agential realism, this theory is used in the analysis as a defamiliarization tool to bring light to the taken-for-granted and, hence, create new understandings of why it is difficult to design innovative IT. The following section elaborates on agential realism as a theoretical lens.

Agential realist analysis

An agential realist analysis does not focus on separate entities and how they interact and affect each other. Instead, this type of analysis focuses on how boundaries are enacted, what material-discursive practices enact them, and how those specific enactments are consequential. However, to examine enactments of boundaries is not uncomplicated, not least since many boundaries are taken for granted and we may not even come to think of questioning how they are coming into being. Here, Barad suggests to study *breakdowns*:

It is often only when things stop working that the apparatus is first noticed. When such (in)opportunities arise the entangled nature of phenomena and the importance of the agential cut and their corollary constitutive exclusions emerges. (Barad, 2007, p. 158)

Since IT design processes often include trial and error and dead ends before finding a design that works, this constitutes an opportunity to identify breakdowns and, thus, notice what apparatuses are at work in enacting the boundaries at hand.

Another way to identify how boundaries are produced by material-discursive practices is through *genealogical analysis*, i.e. to study “the history of how something came to be” (Sefyrin, 2010, p. 56). In agential realist terms, this entails “to see what the specific material configurations look like” (Barad, 2007, p. 211). This means to study how a boundary has been determined and defined over time and what the apparatus (*material* configuration) has looked like. This analysis can inform how that specific material configuration is consequential and makes a difference in the world. That is, an agential realist analysis directs our analytical gaze towards materiality in another way than e.g. positivist or interpretive research. This is a strength when aiming to account for and conceptualize IT in IS research (Orlikowski & Iacono, 2001). Since agential realism focuses on the material and discursive as mutual entailments, both the matter and meaning of IT design can be accounted for.

A challenge in agential realist analyses is to account for how *ongoing, multiple* and *entangled* apparatuses produce phenomena (Barad, 2007). That is, written accounts tend to portray

research phenomena as stable, singular and self-standing. This is also a risk in this thesis and to counteract this, I try to illustrate boundaries' genealogies through historical retrospectives, i.e. how boundaries are enacted differently in different configurations. This makes it easier to notice the *reconfigurings* of boundaries (Scott & Orlikowski, 2014) and, thus, highlights how these are not given but both ongoing and material-discursive. Furthermore, when writing about apparatuses I emphasize that various apparatuses *help* produce specific boundaries, i.e. denoting that there also are other apparatuses at work.

The role of the researcher and theory

In agential realism, to analyze is a material-discursive practice itself and, thus, productive of certain boundaries (as argued in section 3.1.1.). The researcher, theories, analyses and other research practices and apparatuses “are not mere instruments serving as a system of lenses that magnify and focus our attention on the object world, rather they are laborers that help constitute and are an integral part of the phenomena being investigated” (Barad, 2007, p. 232). In this sense, the apparatus for analysis makes a difference in the world. That is, analyses are not innocent descriptions that reflect reality more or less accurately, but are performative of reality. Since research practices are productive of the world – what is included and excluded from becoming – this has ethical implications. Here, IS researchers have a great responsibility to examine and critically review our practices and, thus, our world-making (Cecez-Kecmanovic et al., 2014; Schultze, 2017). We need to pose questions such as; what boundaries do we (re)produce with our research and how are these consequential? and “What kind of world do we want to help make with our theories?” (Schultze, 2017, p. 60). Here, I agree with Schultze’s (2017) belief that agential realism enables an open and generative view of the world and IS phenomena, instead of ‘boxing in’ people and things as stable entities with given characteristics. These queries are discussed further in section 6.4.

Critique of agential realist analyses

Mutch (2013) and Tunçalp (2016) argue that agential realism is lacking analytical clarity as the boundaries of the social and material are blurred, which obscures analyses of relationships. However, the aim of agential realism is not to study how the technological and social interact or impact each other, but to move beyond dichotomies to make sense of the world in new ways (Scott & Orlikowski, 2013). Hence, agential realism may lack analytical clarity from a representationalist perspective but another way to see it is that it opens up for new understandings of IS phenomena, beyond our current assumptions.

Mutch (2013, p. 34) also criticizes that agential realist analyses result in “long lists of factors which produce particular results” but that “no sense of priority is accorded to any of the many factors”. This challenge is a shared feature in studies that deal with complex phenomena, i.e. to account for the many things that are part of and affect the studied phenomenon while also e.g. delimiting our studies, drawing system boundaries, choosing level of analysis and how much details to bring into analyses without drowning in them. This is also a challenge in agential realist analyses, especially since material-discursive practices are

open-ended, ongoing and multiple, thus, making closure impossible (Barad, 2007). However, Barad (2007, p. 449) points out that “not all apparatuses contribute equally to processes of materialization, and genealogical investigations of the most important apparatuses and the nature of their intra-actions are needed for thoroughgoing political analyses”. This means that, to avoid excessively long lists of apparatuses, we should focus our agential realist analyses on the apparatuses that *contribute the most* to the studied phenomenon. This is a recommendation that I try to follow in my agential realist analysis.

3.5. Quality of the research

In positivist and interpretivist research which draw on representationalist assumptions, researchers ask: “How congruent are the findings with reality?” (Shenton, 2004, p. 64) to evaluate their research. Does the research provide an *accurate* description of reality? This is not a valid question in agential realism since the world is not assumed to exist of pre-existing and pre-defined people and things, but is seen as multiple and emergent. So, how does one evaluate the quality of an agential realist study? Here, we cannot rely on the concept of validity since there is no observer-independent, single and correct description of the world. Instead, “it is always possible for there to be different, equally valid accounts from different perspectives” (Maxwell, 1992, p. 283). However, this does not mean that any empirical account will do. Barad (2007, p. 211) points out that “[s]aying something is so does not make it so”. Accordingly, researchers cannot intentionally ‘make things up’ or distort their observations and expect the research to gain credibility and legitimacy (Maxwell, 1992).

Since this study is positioned as critical IS research (as discussed in section 2.7.), the research presented here is seen as historically, socially, politically and culturally situated (Creswell & Miller, 2000). In this sense, researchers’ accounts are not mere *reflections* of the world which are more or less accurate but *diffractions* where the research apparatuses (including the researcher) produce different boundaries in the world (Barad, 2007). That is, what researchers see depends on their perspectives and situatedness – their entanglement – in and with the world (Barad, 2007; Creswell & Miller, 2000). Accordingly, to demonstrate the rigor of a study, researchers have to account for the apparatuses which are part of producing the research and the research results (as mentioned in section 3.1.1.).

Barad (2007) highlights that descriptions and explanations of phenomena have to include both discourse and materiality to become empirically adequate accounts and that not all practices matter equally for producing phenomena. Here, detailed observations in the field where the researcher becomes entangled with the practices in the case can provide a more nuanced and rich description than shallow or ‘at-first-sight’ accounts, which may be more prone to misinterpretations and loss of details that make differences in the world. Detailed field studies enable researchers to be attentive to details and multiple practices and boundaries, producing more of a diffractive account than a mere ‘reflective’. Accordingly, transparent accounts of the research apparatuses open up for the reader to scrutinize the research practices and apparatuses to deem for themselves if the research is relevant and rigorous. This is similar to interpretive research in which researchers are to provide reflexive

accounts of the research process to report how they may have influenced the research (e.g. Alvesson & Sköldbberg, 2017). The difference lies in that in agential realism, researchers are part of producing both matter and meaning, not only constructions. It should also be pointed out that apparatuses are open-ended (Barad, 2007), making a *complete* account of the research apparatuses impossible.

3.5.1. Generalizability

Generalizability is tightly coupled with positivist and quantitative research, including to generalize to a population and to make predictions (Lee & Baskerville, 2003). However, there are also other notions of generalizability that are applicable to qualitative research. To generalize can be defined as “to form general notions by abstraction from particular instances” (Lee & Baskerville, 2003, p. 232). Here, generalizability entails that these general notions, or theories, can be useful when making sense of similar situations or phenomena (Maxwell, 1992). The aim of this thesis is not to develop a theory but to provide explanations and improve our understanding of why it is difficult to design innovative IT. Gregor (2006, p. 625) argues that when applying theories for explaining, judgments of the contribution is made “on the basis of whether new or interesting insights are provided”. Accordingly, a core criterion for evaluating the quality of the research is to discuss the extent to which the study makes such a knowledge contribution. This is discussed in section 6.3.

3.5.2. Research ethics

Another important aspect of research quality is ethical considerations. The Swedish Research Council (2011) (abbreviation VR in Swedish) argues that a good research practice does not only produce research with good scientific quality but also is conducted in an ethically sound way. This includes to be truthful and open about the research, to give credit where credit is due and to be “clear, critical and honest in evaluating sources of error” (VR, 2011, p. 45). As mentioned above, I try to be as transparent as possible in this thesis so that the readers may judge for themselves if they find any unethical conduct. In the following paragraphs, I describe informed consent and confidentiality as important ethical considerations. How these matters have been addressed in this study is elaborated in section 6.4.1.

The overarching aim of informed consent and confidentiality is to protect participants (e.g. respondents) from any harm – physical, emotional, humiliation or invaded privacy (Fontana & Frey, 1994; Payne & Payne, 2004; VR, 2002). Informed consent refers to that people agree to participate in a study after being informed about the research (Fontana & Frey, 1994). The information should account for what the research is about, who is conducting it and why, and how the empirical data will be used. The information should be as full as possible and participants should be informed about matters that could make them want to withdraw from the study. Participants should also be informed that consent is voluntary and that they can leave the study at any time without explanation or consequences (Payne & Payne, 2004; VR, 2002).

When conducting participant observation, it is difficult to assess whether all participants consent at all points in time. The researcher may have initial consent from participants but this may change over time or new participants may enter along the way (Dingwall, 1980). Dingwall (1980, p. 878) argues that “it is impractical to obtain consent on each and every occasion without causing total disruption”. Accordingly, to produce rigorous research, informed consent has to be balanced with the risk of being obtrusive. Jorgensen (1989, p. 46) points out that “[t]he most ideal situation [when conducting participant observation] is one in which authorities and other people in the setting welcome the researcher”. In this sense, the participants are in control of when they consent to taking part in the study. Informed consent is especially important when using video recording as participants can be identified (as opposed to e.g. surveys) which can intrude on the participants’ integrity and privacy (VR, 2011). In video-based research, it is custom to obtain written informed consent from all participants (Heath et al., 2010; VR, 2011).

Researchers also have to consider confidentiality, which refers to that empirical data should be protected from access of unauthorized individuals (VR, 2011). This includes video and audio recordings, photos, transcripts, field notes and the like (Myers & Newman, 2007). When reporting the research, the researcher also has to make sure that participants cannot be identified by outsiders, in order to protect participants and their rights to privacy (VR, 2002). By following these ethical guidelines, the researcher can protect participants from any harm related to the research. The ethical aspects of this study are elaborated in the following sections.

3.6. Research process

The previous sections accounted for and discussed the methodological choices made in this thesis. In the following section, the research process is described to give the reader an overview and a transparent account of the research practices and apparatuses in the study. The case is divided into two phases – the innovation contest and the IT design project (presented in detail in the next chapter). The fieldwork started in February 2014 and ended in October 2015. I observed 26 occasions resulting in approximately 44 hours of participant observation and conducted three semi-structured interviews. The generated empirical material is summarized in Table 3.1.

The research in this thesis has been processed and presented in various settings, including seminars, PhD courses and colloquiums. The research has also been presented in workshop and conference papers where initial ideas of research topics, research questions and theoretical lenses have been discussed and early analyses of the empirical material have been published. Accordingly, the research has partly been peer-reviewed, open to scrutiny and discussed in both national and international contexts, but the main part of the material presented in the thesis is novel. A list of scholarly work that discusses parts of the research in the thesis is presented below (newest first):

1. Wassrin, S. (2017). Becoming with research – Methodology from an agential realist perspective. Presented at After method in organization studies III, Västerås, Sweden, 27-29 September.
2. Wassrin, S. (2017). An agential realist perspective on inertia and change in IT design. Presented at Open seminar on Sociomateriality: Exchanges on theory and empirical issues, Uppsala, Sweden, 8-9 May.
3. Wassrin, S., Lindgren, I., & Melin, U. (2015). Open innovation contests for improving healthcare – An explorative case study focusing on challenges in a testbed initiative. Presented at the 14th IFIP Electronic Government (EGOV), Thessaloniki, Greece, 30 August - 2 September. [Granted the Outstanding Paper Award in the category 'The Most Innovative and Promising On-Going Research.']
4. Wassrin, S., Lindgren, I., & Melin, U. (2015). Open innovation competitions for improving health care – An explorative study focusing on challenges. Presented at the 12th Scandinavian Workshop on E-government (SWEG), Copenhagen, Denmark, 3-4 February.
5. Wassrin, S. (2015). Innovation contests in IT design: How pressures for innovation may impede innovation. Presented at the 38th Information Systems Research Conference in Scandinavia (IRIS38), Oulu, Finland, 9-12 August.
6. Wassrin, S. (2014). Understanding the Processes of Online Creative Interaction – Toward a Research Agenda. Presented at the 37th Information Systems Research Seminar in Scandinavia (IRIS 37), Ringsted, Denmark, 10-13 August and published as Selected Papers of the IRIS, Issue Nr 5, 95-105.

3.6.1. Case selection and defining the research question

Since the empirical case and the research question are important apparatuses which make the researcher focus on some aspects at the exclusion of other aspects, I will here describe how the case was chosen and the research question emerged. When starting as a PhD student in November 2013, my initial interest revolved around creativity and innovation in organizations and especially why these matters seemed to be difficult and how they could be achieved. Although it may be difficult to tease out exactly why someone becomes interested in a specific topic and not others, a contributing factor to my interest is my upbringing and prior work experiences in the performing arts where creativity is a core feature. In my bachelor studies in behavioral sciences and Human Resources, the difficulties of change was a prominent topic which also spurred my interest. Accordingly, the question addressed in this thesis partly stems from a long-held curiosity about the opportunities and challenges of creativity, change and innovation.

When I was introduced to the opportunity to follow the innovation contest, I saw this as a possibility to study the topics I was interested in. Case selection may be due to many aspects but one essential criterion for choosing a case is whether it allows researchers to study the phenomenon of interest. Jorgensen refers to this as *theoretical sampling*, that is:

[A] form of nonprobability sampling that depends on the researcher's ability to make decisions about what to observe based on constraints such as opportunity, personal interest, resources, and, most important, the problem to investigated. (Jorgensen, 1989, p. 50)

Access is another important aspect when selecting a case (Brown, 2014; Stake, 1994). Accordingly, the case was selected on these grounds – interest, opportunity and access.

Table 3.1. Overview of the empirical material in the case study

Phase	Data generation technique	Event	Participants	Documentation	Number of pages	Duration H:MM	Date
Phase I The innovation contest	Participant observations	Introductory contest meeting 1	Project team	Field notes	2	2:00	2014-02-13
		Introductory contest meeting 2	Project team	Field notes	3	2:00	2014-02-26
		Introductory contest meeting 3	Project team and organizations interested in the contest	Video recording and field notes <i>The project teams' video recording</i>	2	2:30	2014-03-24
		Contest meeting	Project team and competing team	Field notes	5	2:00	2014-06-12
		Contest meeting	Project team	Field notes	1	0:50	2014-06-16
		Contest meeting	Project team and competing team	Field notes	2	1:10	2014-06-16
		Evaluation meeting	Project team	Field notes	3	1:30	2014-06-16
		Meeting for marketing	Project team representatives	Field notes	2	2:00	2014-06-17
		Contest meeting	Project team	Field notes	2	1:00	2014-09-18
	Semi-structured interviews	Contest finale	Project team and competing team	Field notes	9	2:30	2014-10-02
		Interview 1	IT consultancy manager	Audio recording and transcript	9	0:45	2014-10-09
		Interview 2	Testbed manager	Audio recording and transcript	9	0:45	2014-10-10
	Documents	Interview 3	Clinic representative	Audio recording and transcript	8	0:30	2014-10-13
		Project documentation		Documents from the project, e.g. several versions of the contest rules, PowerPoint from the project team and competing team	239		

The table continues on the next page.

Table 3.1. Overview of the empirical material in the case study (cont.)

Phase	Data generation technique	Event	Participants	Documentation	Number of pages	Duration H:MM	Date
Phase II The IT design project	Participant observations	Project meeting	Clinic and VTI researchers	Field notes	4	2:00	2015-01-27
		Project meeting	Clinic and students	Audio recording and transcript	49	1:15	2015-01-29
		Workshop	Clinic and students	Video recording and transcript	61	1:50	2015-02-11
		Project meeting	Clinic	Audio recording and transcript	54	1:50	2015-02-25
		Workshop	Students and patients	Video recording and field notes	7	2:40	2015-03-18
		Project meeting	Clinic and VTI researchers	Audio recording and transcript	67	2:25	2015-03-30
		Testbed meeting	Testbed team and LiU researchers	Field notes	7	2:00	2015-04-17
		Project meeting	Clinic and students	Audio recording and transcript	17	0:50	2015-04-27
		Workshop	Students and patients	Video recording and field notes <i>(the participants recorded the video)</i>	1	1:10	2015-05-11
		Project meeting	Clinic and IT consultancy company	Video recording and field notes	4	1:50	2015-05-25
		Testbed meeting	Testbed team and LiU researchers	Field notes	1	1:50	2015-06-17
		Testbed meeting	Testbed team and LiU researchers	Field notes	4	2:00	2015-08-27
		Project meeting	Clinic	Audio recording and field notes	1	1:00	2015-10-07
		Procurement meeting	Clinic, testbed and procurement personnel	Field notes	3	0:30	2015-10-27
	Project meeting	Clinic and VTI researchers	Audio recording and field notes	4	1:30	2015-10-28	
Documents	Delivery of prototype	Clinic and IT consultancy company	Video recording and field notes	1	1:45	2015-12-15	
	Project documentation		Documents from the projects, e.g. requirement specifications, meeting documents, e-mails, medical reports, and the students' Master thesis	153			

However, although the research process may start with a theoretical interest or abstract idea, exactly what will be the focus of the study is often defined and redefined throughout the research process. This means that data generation, analysis and the process of defining the research phenomenon and research questions are ongoing, iterative and overlapping processes which affect each other (Brown, 2014; Payne & Payne, 2004). This iterative process is often seen in qualitative research in general, but in participant observation in particular. Questions, ideas or areas of interest may emerge during observations, which will help to guide and focus the subsequent observations. Accordingly, initial observations should be broad in scope and then narrowed down, although the researcher must be open to that the issues or problems for study may change or need to be redefined as new information emerges in the participant observations (Jorgensen, 1989).

This description reflects the process in this study. As I started out my participant observations, I had topics of interest but not a clear agenda and knew very little of the setting. Hence, the basic aim of the preliminary observations were to become familiar with the context and events (Jorgensen, 1989). The researcher is to “remain open to the unexpected” (Jorgensen, 1989, p. 82) in these early phases. As I did not know what to expect when entering the field, my observations were naturally unfocused and broad and I remained a passive participant in the beginning of the study. As I became more familiar with the setting and the events in the case, my observations became more focused, which also led me to participate to a greater extent during the observations. The process of narrowing down the scope was also affected by the fact that the thesis should contribute to the IS field. This made me focus on IT artifacts in the case and IT design in particular. Accordingly, during my time in the field, the research question was teased out along the way in relation to the things happening in the case, my initial interests and IS literature that I read during the case study. Accordingly, the phenomenon was not predefined but emerged during the case study. My analytical foci are elaborated in section 3.6.4.

3.6.2. Phase I – The innovation contest

During the innovation contest, I conducted participant observations on 10 occasions resulting in approximately 17,5 hours of observations. I participated in meetings before, during and after the contest, e.g. when the contest was planned, when it was carried out and when it was evaluated. One of these occasions was a video recording that the participants made for marketing purposes. This was accessed on the contest website.

In this phase of the case, my level of participation was fairly low as I kept in the background and only occasionally asked questions, e.g. for clarification of concepts or meanings, which Jorgensen (1989) refers to as *informal interviews*. I often asked these questions before and after meetings as this did not interrupt the activities that the participants had gathered for. While observing, I took field notes by writing down what I heard and saw. I used pen and paper as I found this to be less obtrusive than sitting behind a laptop during the observations – the participants seldom brought laptops of their own and, hence, I tried to follow their custom. The handwritten field notes were elaborated shortly after the observations in

a word processing program. Payne and Payne (2004) argue that as much as possible should be included in the field notes in the beginning of a case study as it is difficult to say what will become relevant later in the research process. My field notes during this phase were broad and general, focusing on descriptive questions such as *who*, *what*, *when*, *how*, and *where*.

By the end of the innovation contest, I conducted three semi-structured interviews. The interviews ranged from 30-45 minutes each. When selecting respondents to interview, a diverse set of perspectives should be included, according to Myers (2013). This is echoed in this study as I chose to interview one representative from each group of participants involved in the contest. An interview guide was used in the interviews (see Appendix A). The main focus in the interviews was the respondents' reflections on the innovation contest – how the process had played out, expectations versus outcomes of the contest and thoughts on innovation as a concept. The interviews were conducted face-to-face and took place at the respondents' respective offices. The interviews were audio recorded and transcribed to enable detailed data and verbatim quotes. Before the interviews, the respondents were informed about the aim of the interview and they were asked for consent to record. I also informed the respondents that participation was voluntary, that they could refuse to answer any question and that they could end the interview at any time. In addition to recording the interviews, I also took notes, but these were brief since I wanted to focus my attention on the respondent and be an active listener.

Throughout the first phase of the case, I also gathered documents used in the innovation contest. These included plans and rules for the contest, flyers, requirement specifications, presentations from the contestants and e-mails. I also gathered documents about the funding premises of the contest, reports from the contest project team to the funding agency and news items about the contest. These provided me with additional contextual information and helped me understand what the participants in the case referred to.

3.6.3. Phase II – The IT design project

The innovation contest resulted in two subsequent IT design projects (elaborated in Chapter 4). I continued to follow both of these projects since they provided the opportunity to study IT design and innovation in more detail and for a longer period. However, one of these projects became more salient than the other since it provided access to closely follow design workshops and the design process. This project is put in the foreground in Chapter 4, whereas the other project functioned more as a contextual reference point as many of the participants were involved in both projects. During this second phase of the case, my initial observations and readings of IS literature had led me to focus on IT and especially the materiality of IT and IT design (elaborated in section 3.6.4.) and, hence, the participant observations were complemented with video and audio recordings to generate more detailed empirical material.

During the IT design project, I conducted participant observations on 16 occasions resulting in approximately 26,5 hours of observations including video and audio recordings. Also in this phase, I took field notes and conducted informal interviews but I actively

participated more, e.g. tried out potential technological solutions together with the participants. The point of participating, in contrast to just observing, is that the researcher can gain first-hand experience by engaging all senses (Esterberg, 2002). This is advantageous to understand the participants' experiences and also to encounter the IT artifacts in use. My field notes became more focused during this phase as areas of interest and initial analyses emerged. I also noted hunches and my own experiences and explanatory aspects concerning *why* certain things happened. In addition, I also took photos to complement my field notes. Some of the video and audio recordings were transcribed verbatim, others were documented as detailed field notes and yet others were a combination of detailed field notes and transcripts. This resulted in 272 pages of field notes and transcripts. The transcriptions were conducted by me and one other person which had been informed about research ethical issues.

Jorgensen (1989) argues that the longer or more frequently the researcher is participating, the more likely it is that other participants take the researcher for granted and find her less threatening. I was invited to meetings in the same way as other participants, which indicates their acceptance of my participation. This process of gaining access and acceptance as a researcher is also beneficial when aiming to video record observations. It is advised that the researcher conduct observations without any recording equipment in the initial stages of research to gain acceptance and trust from the participants (Corsaro, 1982; Heath et al., 2010). Accordingly, introducing recording equipment at a later stage in the observations is less obtrusive. This is echoed in this case where initial observations established acceptance and rapport with the participants, facilitating the introduction of recording equipment.

When video recording the observations, I used a digital video recorder placed on a tripod. This fixed position is advantageous in settings where there are few participants that do not move around too much (Heath et al., 2010). A fixed position also enabled me to take notes and engage in the participant observations, as opposed to a handheld camera. I chose a position for the camera that I found to be as unobtrusive as possible. Video recording can also take place without the researcher being present in the setting. For instance, the participants can assist the researcher with starting and stopping the recordings (Heath et al., 2010). I used this strategy on one occasion when I could not participate myself as I attended a PhD course abroad. I provided the clinic with instructions and prepared the equipment to make the process as easy for them as possible. They were also instructed to inform new participants about the research and gather written consent.

I also used audio recording equipment extensively during observations. The audio recorder was used both as a complement to video recording but also in observations where I did not video record. Audio recordings enable detailed transcripts of the observations which complement field notes. The audio recorder was often placed in the center of the table at the meetings and workshops. Before audio-recording the meetings, I always asked participants if they agreed to being recorded. To exemplify, there have been meetings where new participants have been uncomfortable with being audio record, and hence, I have only taken field notes during these occasions.

Furthermore, when taking photos and video recording, the researcher is actively deciding what to focus on, from what angle and at what time (Heath et al., 2010; Jorgensen, 1989; Myers, 2013). Hence, the foci in the recordings are affected by my interests and analytical lenses. This is an illustrative example of how I as a researcher is actively generating the data. For instance, I sometimes moved the video recorder to get a better view of how the participants used different IT artifacts.

Both participant observations and recording equipment are obtrusive and may affect participants and their conduct. During this fieldwork, participants sometimes commented on the recording equipment, often jokingly. These comments usually took place in the beginning or ending of meetings, whereas the participants focused on their work tasks in the middle of the meetings. Apparently, my presence as a researcher affected the participants and the data to some extent. To be as unobtrusive as possible, I arrived early to the meetings to be able to set up the equipment without interfering with the meeting or missing out opportunities to talk to participants.

Since informed consent is important in research in general but in video recording in particular, I gathered written consent from the participants. Participants got an agreement form with information about the research and were asked to sign it if they consented to participating in the study. For most of the participants, this information was sent out by e-mail a few days before the video recording. This way, they had time to read it without any pressure to sign and they also had the chance to ask questions (Heath et al., 2010). I also informed verbally at every video-recorded meeting, as the Swedish Research Council (2011) recommends. The information on the agreement included a description about me, i.e. that I was a PhD student at Linköping University, what I studied in my thesis and why I wanted to use video recording in my research. It was also clearly stated that participation was voluntary, that they could end their participation at any time without leaving any explanation and without consequences. It was also stated that the video material would only be used for research and education, be stored so that no one unauthorized could take part of it and that the results from the study would be reported so that the participants could not be identified. The agreement also contained my contact information, so that participants could reach me if they had any questions or wanted to withdraw their consent. The agreement was signed by me and each participant and both parts got a copy of the signed agreement.

I also gathered documents used in the IT design project. These included requirement specifications, e-mails and reports which the participants worked with or referred to. The documents were mainly used to understand the context and the topics which the participants discussed. The fieldwork ended when the IT design projects entered a new phase with focus on procurement, which was outside the scope of this thesis. By the time of this, I had generated a large amount of empirical material over a long period of time which was considered sufficient for analysis and to answer the research question. How analyses were carried out is elaborated in the next section.

3.6.4. Analysis

As indicated above, analysis is rarely a separate phase from that of data generation in qualitative research (Myers, 2013). In this thesis, the analysis has been conducted iteratively with data generation. The empirical material has been analyzed repeatedly both through data-driven and theory-driven analyses. The data-driven analysis of the empirical material included explorative and open coding (Myers, 2013) of field notes, transcripts from video and audio recordings and documents. I also reviewed the recordings by watching and listening to them. In the initial rounds of coding, I focused on recurring topics to get an overview of the material. This included that I highlighted quotes and keywords, making comments and initial codes in the margins of the transcripts and documents. These initial codes were then compiled to get an overview of what topics seemed most important. For instance, the participants in the empirical case often came back to specific features of the IT artifact, e.g. steering wheel and screen. This sparked my interest – why were these features so important? The participants also emphasized social aspects such as medical knowledge and patients' experiences. This led me to go through the empirical material additional times where I focused more on questions that had been raised from the initial rounds of coding. Why did the participants come back to some topics over and over again? Why was it difficult for them to come to a mutual understanding of these design features? Why were some designs considered possible and others impossible? And why were they sometimes uncertain if a suggested design was impossible or not?

After multiple readings and sorting the material in different ways, what always came back was that some design suggestions and features were problematic. This led me to focus on these and turn to research literature that could help explain what I saw in the empirical material. For instance, by the time of my data-driven analysis, I attended PhD courses and participated in seminars where the debate of theorizing and conceptualizing the IT artifact (Orlikowski & Iacono, 2001) was discussed. These activities also included readings about sociomateriality. This led me to look at my empirical material with these aspects in mind, e.g. what role did the materiality of IT play? This question fit well with what I saw in my data-driven analyses. That is, the participants repeatedly came back to specific design features which led me to wonder about the materiality of the design – what role did it play? And how did it relate to the social aspects in the empirical material?

To help me think about these questions, I consulted different theories which I tried as lenses. This is in line with Jorgensen (1989, p. 110) who argues that “[a]s different ways of arranging materials are explored, you may find it useful to consult or revisit existing literature and theories related to your problem”. My readings included e.g. ANT, Pickering's (1993) mangle of practice, Leonardi's (2013) imbrication and Bjørn and Østerlund's (2014) sociomaterial-design. I also explored discourse analysis as a potential lens. The readings of sociomateriality in the IS field led me to the works of Orlikowski and Scott, and through them to Barad's (2007) agential realism. Accordingly, I explored many possible theoretical lenses before settling for agential realism. I found that agential realism provided a vocabulary that helped shed light on both the material and social aspects which I had

identified in my data-driven analysis. Accordingly, I conducted additional rounds of analysis of the empirical material with agential realism as a theoretical lens.

In this theory-driven analysis, I first focused on the IT artifact as an apparatus and explored what boundaries it produced. This led me to examine the material configurations of the design of the IT artifact. Here, it was helpful to be able to contrast the existing IT design to that of suggested new designs that were considered impossible or uncertain. These designs can be considered *breakdowns*, i.e. instances when things do not work which help us notice the apparatus (Barad, 2007). Hence, the impossible and uncertain designs helped identify the boundaries produced by the existing IT design. Next, I changed focus to asking *why* some IT designs were impossible, possible or uncertain. This analysis was inspired by genealogical analysis where I made historical retrospectives to understand and explain how specific boundaries had come into being and why some enactments or boundaries were impossible, possible or uncertain. This helped to shed light on why certain material configurations (designs) were difficult or impossible to change. This analysis is presented in Chapter 5 where I have tried to make the account as transparent as possible.

This chapter has presented the research approach of the thesis. The aim has been to give the reader a transparent account of the methodological choices made and how the research has been conducted, including philosophical assumptions, research method, data generation techniques, analytical approaches and quality aspects. In the next chapter, the empirical material of the thesis is presented – the driving simulator case.

4. The driving simulator case

This chapter presents the driving simulator case study, which constitutes the empirical foundation of the thesis. This is a case where participants in an IT design project aim to design a new medical device to be used in healthcare. The chapter is divided into two parts. The aim of Part I is to give the reader an overview of the case by describing the context, the participants, the driving simulator and processes in the case. Part II focuses on the design of the new IT artifact in which possible, impossible and uncertain designs are identified.

4.1. Introduction

The following empirical account presents the driving simulator case study, which constitutes the empirical foundation of this thesis. The case revolves around a *driving simulator* – a medical device used at a specialist clinic in a Swedish hospital to assess people’s fitness to drive a vehicle after brain injury. This driving simulator is considered old and unreliable by the health professionals who use it. Due to this, an attempt to design a new device to make these assessments was launched. This endeavor started out as an innovation contest which turned into two subsequent design projects. In this sense, this case is an example of an attempt to design innovative IT in a highly regulated context including strong professions, users with specific and specialized domain knowledge and areas of expertise and a legacy system still in use. Thus, this case provides a great opportunity to study why it is difficult to design innovative IT, especially in contexts with many barriers to radical innovation. The chapter is divided into two parts. Part I introduces the case whereas Part II focuses on the design of the new IT artifact, identifying possible, impossible and uncertain designs.

Part I – Introducing the case

The aim of Part I is to give the reader an overview of the case by describing the context, the participants, the driving simulator and processes in the case. The main participants in the case are introduced in boxes as they enter the story. This is to make it easier for the reader to go back to them, if needed.

4.2. Assessing patients’ fitness to drive

In Sweden, physicians are required by law to assess if people with driver’s licenses are in condition to drive safely after brain injuries. Persons that have been subject to diseases or injuries in the brain can suffer from deterioration in their cognitive and intellectual abilities, such as perception, attention, simultaneous capacity, judgment and reaction time. For a car driver, this means that the risks for making serious errors while driving increase significantly. If the person is not in condition to drive, the physician must report this to the Swedish Transport Administration, which may withdraw the driver’s license.

Approximately 3 in 1000 Swedish citizens are subject to stroke every year and a similar amount are exposed to head trauma resulting in injuries in the brain, according to the specialist clinic (presented in Box 4.1. below). Other groups of patients with brain impairments include chronic neurological diseases and dementia. Not all of these patients acquire brain injuries that will stop them from driving safely, but for some, the cognitive impairments will inhibit them from driving. Furthermore, patients may not be aware of their impaired abilities and, thus, may think that they have not changed since before the injury or disease.

Patients' abilities to drive are assessed both in primary healthcare and specialist clinics. At primary healthcare centers, health professionals screen patients by using cognitive tests, such as paper-and-pencil tests. These screening tests are used to identify patients with severe cognitive impairments that make them unfit drivers. Borderline cases that need further assessment are remitted to the specialist clinic in the region where a more detailed examination is performed, using specialized assessment tools.

Box 4.1. The specialist clinic

The specialist clinic (hereafter referred to as the clinic) is a clinic specialized in traffic medicine, located at a university hospital in a Swedish region. The clinic's area of expertise is patients with brain injuries entailing cognitive impairments. The main activity at the clinic is to assess these patients' fitness to drive a vehicle. The clinic focuses specifically on the cognitive conditions in their assessments. This means that patients need to be investigated regarding other known medical hindrances for car driving, such as visual defects (i.e. visual field loss) and moderate to severe dementia, before being remitted to the specialist clinic. Professions at the clinic are occupational therapists, psychologists and physicians specialized in rehabilitation medicine. The clinic is fairly small (approximately ten health professionals) and is part of a larger clinic.

Three health professionals from the clinic have been involved in the activities in this case study – a chief physician and two occupational therapists. The chief physician is in charge of the clinic and the medical assessments. One of the occupational therapists works with the assessments of the patients by using cognitive tests and the driving simulator. The other occupational therapist is an associate professor coordinating research and development initiatives at the clinic.

At the specialist clinic, assessment is carried out by physicians and occupational therapists. They review the patient's medical history in regard to driving and conduct neuropsychological screening to test basic cognitive functions. The latter is done by use of cognitive tests, e.g. paper-and-pencil and computerized tests. For instance, the clinic uses a test where the patient is to react to stimuli on a computer screen by pressing on symbols on a touch screen. They also use paper-and-pencil tests which are similar to the computerized tests, but the patient uses a pencil to e.g. draw lines between or cross out stimuli presented on a paper. These tests assess patients' cognitive abilities, e.g. focused and divided attention and their processing abilities. However, the predictive power of these types of tests are considered limited since they do not replicate the challenges and complexities in car driving, according to the clinic.

The clinic also uses a driving simulator in which patients' attention, reaction, simultaneous capacity and processing ability are assessed. This test is more dynamic than the screening tests as the patients are to act and react in various ways. Furthermore, the cognitive tests and driving simulator are sometimes complemented by observing the patient in an actual driving situation where the patient drives a driving school car together with a certified driving school teacher and an occupational therapist. This part of the assessment is mainly used for the most difficult borderline cases since it is not possible to assess all patients this way.

4.2.1. Introducing the driving simulator

The driving simulator, which is the artifact that this case revolves around, is a medical device used to assess patients' cognitive conditions to drive. It consists of three computer screens staged on a table, a steering wheel (with a set of buttons) attached to the table surface, a screen for the health professionals operating the test and three computers (see Figure 4.1. and 4.2.). The test is divided into three phases. In the first part of the test, i.e. in the primary task, the patient gets a chance to get acquainted with the setup. Here, focus is on the middle screen which displays a road and the task is to keep the car on the road. The road is straight, without curves, but wind is simulated, pushing the car to the left and right. The driver must then compensate for the wind and keep the car on the road by turning the steering wheel. The aim of the first phase is to make the patients become familiar with the steering wheel and the task, e.g. how much or little they must turn the steering wheel to keep it on the road. But this phase is also used to adjust the level of difficulty to the individual. During this phase, the test adds more and more wind until the patient has reached a level of difficulty in which she has to stay focused and attentive but still manages to keep the car on the road.

The next phase of the test focuses on the screens to the left and right, i.e. the secondary task. These screens display red and white triangles, resembling yield signs. These yield signs sometimes include a black arrow. The patients' task is to react as rapidly as possible to the direction of the black arrow by pushing the buttons on the steering wheel. This means that the arrow may occur on the right screen but point left. The patient is then to press the left button as fast as possible. The patient does not steer during this part of the test.

In the last phase of the test, the two prior tasks are merged. That is, the patient is simultaneously steering (compensating for wind and keeping the car on the road) while at the same time paying attention and reacting to the directions of the arrows by pushing the corresponding buttons on the steering wheel.

During the test, the occupational therapist takes notes on the patients' motor skills and their abilities to understand the instructions, communicate and concentrate. When the test is completed, the occupational therapist has to extract the test result data by taking the floppy disk from the driving simulator to another computer in another part of the hospital. There, she gets a report with numbers of the patients' performances. Since the test results cannot be extracted instantly, the occupational therapist presents and explains the results to the

patients at a later appointment. The notes and results from the test, together with the other medical assessments, are then basis for decision whether the patients are fit to drive and get to keep their driver's licenses or not.

Figure 4.1. The old driving simulator from the front

Figure 4.2. The old driving simulator including the health professional's screen to the far left

The driving simulator was developed in the 1970s. The clinic referred to it as ‘the old driving simulator’ or ‘the old sim computer’ and even though they called it a ‘simulator’, they argued that it was not a real simulator but rather a tracking task. The clinic considered the technology to be old and unreliable as it often broke down or did not work as intended. It had also proven difficult for the hospital’s IT department to support and provide maintenance for the technology as the computer runs on a DOS system and uses floppy disks. There was no longer any personnel at the IT department that had the competence to support the technology, i.e. to write DOS code, and there had also been difficulties in finding spare parts for maintenance.

Since a retracted driver’s license entails both possible professional and social restrictions in a person’s life, the clinic argued that it is important that the medical assessment, on which this decision is made, is sound. According to the clinic, cognitive impairments are difficult to determine or measure in regular clinical examinations:

You need a tool to assess this, it’s not possible to assess just by face-to-face interaction. (Occupational therapist, 2014-10-13)²

Hence, the clinic argued that a new assessment tool to test patients’ cognitive abilities for car driving was needed. In their communication with the IT department, the clinic got in contact with the testbed at the hospital (see Box 4.2). The personnel at the testbed suggested that something should be done about the driving simulator to solve the clinic’s problem, instead of just maintaining the old driving simulator. However, to do this, funding was needed.

Box 4.2. The testbed

The testbed can be described as a test environment for developing and evaluating innovations for future healthcare. It is meant to work as a platform for employees in healthcare and external businesses to test, implement and validate products and ideas for the healthcare system in a realistic but risk-free context. It also aims at enabling collaboration between health professionals, patients, companies and innovators. The testbed is located at the regional university hospital and is supported by the Swedish innovation agency Vinnova, in collaboration with academia and the industry.

Three employees from the testbed have been involved in the activities in this case study. These are also employed at the department responsible for medical technology and IT in the region and hospital. Their competences include biomedical engineering, computer science and medical informatics.

4.3. Launching an innovation contest

By the time of the clinic’s and testbed’s discussions about solving the problem with the old driving simulator, Vinnova (Sweden’s innovation agency) announced funding programs for innovation contests. The aim of the program was to increase the use of innovation contests in Swedish organizations, to stimulate innovation through non-traditional innovation processes and make organizations open up their innovation activities by inviting external

² All quotes in this chapter are translated from Swedish to English by the author.

actors. In their announcement, Vinnova emphasized that they were only going to fund contests with a clear innovation goal, e.g. incremental or radical innovation. The agency emphasized that the contests should have the potential to meet a demand related to an identified problem or need and that the solution should be scalable so that the innovation could be widely distributed.

The testbed and clinic applied for the funding program, but in order to meet the criteria stipulated by Vinnova, they changed focus from the clinic's problem to that of primary healthcare. The reason for this was that the outcome of the contest had to be scalable and widely distributed. Since a solution for the specialist clinic only would have benefitted themselves, this was not considered a scalable solution. Hence, they changed focus to primary healthcare as they argued that healthcare centers lacked tests to assess cognitive abilities related to driving. The clinic also argued that such a test could be used to screen more patients in primary healthcare instead of remitting them directly to the specialist clinic. Consequently, this could diminish the workload for the clinic.

The testbed and clinic were granted funding from Vinnova to launch an innovation contest.³ The contest was led by the project manager from the testbed and the project team consisted of two additional employees from the testbed and three health professionals from the clinic. However, when the contest was launched, it did not attract any participants. Instead, the project team tried to headhunt teams to recruit participants to the contest. They were especially looking for participants that could be interested in cooperating also after the contest. They managed to recruit one team, an IT consulting company (see Box 4.3.). Even though there was only one competitor in the contest, the project team followed through with the contest.

Box 4.3. The IT consulting company

The IT consulting company is a company located in the region, providing consulting services regarding information and communication technology. The company works with both private and public sector and is part of a group with its focus on a Nordic market. The group has existed in approximately twenty years and has 1300 employees.

Several employees from the IT consulting company have been involved in the activities in the case study, however, the participants have varied. These have mainly involved IT consultants who have not been assigned other consultancy projects at the time. Examples of participants are consultants, a consulting manager and system developers.

According to the contest rules, written by the project team, the aim of the contest was to develop a relatively simple and secure method to be used in primary healthcare to assess patients' abilities for safe driving after brain injury. In these rules, 14 requirements were specified, which were to be used in the evaluation of the contest entries (Appendix B).

³ For a more detailed account and analysis of the innovation contest as a means to improve healthcare, see Wassrin, Lindgren and Melin (2015).

The competing team talked to health professionals both at the specialist clinic and in primary healthcare to learn about the situation. They developed a prototype where they made a tablet version of a paper-and-pencil test. According to the clinic, this prototype had some appealing features but did not solve the challenge of the contest. However, the clinic thought that a positive outcome of the contest was that they had identified a collaboration partner who they could work with in subsequent projects. Both the competing team and the clinic wanted to continue their collaboration. The competing team was chosen as winners of the competition and was awarded two gaming racing wheels.

4.4. The subsequent design projects

The innovation contest resulted in two parallel projects. One project focused on the needs of primary healthcare and involved the clinic and the IT consulting company. The other project focused on the needs of the specialist clinic and involved the clinic and VTI (see Box 4.4.). In this thesis, focus is on the former project with the IT consulting company, but comments will be made regarding the VTI project, since the projects affected each other.

Box 4.4. The Swedish National Road and Transport Research Institute (VTI)

The Swedish National Road and Transport Research Institute (VTI) is a research institute conducting research regarding the transport sector, e.g. traffic safety. They develop driving simulators and other research equipment relating to traffic. The research results are often used as a basis for decision making in the transport sector and transport policy. VTI performs interdisciplinary research both nationally and internationally and employs approximately 200 people.

Three employees from VTI have been involved in the activities in the project. These are researchers in cognitive psychology focusing on traffic issues, e.g. elderly drivers, impairments and simulators.

The IT consulting company involved two students (see Box 4.5.) to work on this project. The students received the list of the 14 requirements from the contest. These were discussed during an initial meeting between the students and the clinic, where the students could ask questions to get clarifications and input for their requirement elicitation. The clinic also showed the students how the old driving simulator worked.

Box 4.5. Students

The IT consulting company engaged two students from the university located in the region to work on the project. The students studied media technology and computer science and worked with the project as part of their Master thesis. The students had no previous knowledge of cognitive assessments or development of medical equipment. They were supervised by an IT consultant from the IT consulting company who had been involved in the contest. This consultant also participated in the project, e.g. took part in meetings and workshops.

The two students applied a user-centered design approach in the project and designed a prototype which will be described in this chapter.

The students arranged a workshop where the clinic got to test possible technological solutions. According to the students, the aim of the workshop was to investigate the

requirements further, explore how the requirements could be met and how medical assessments of cognitive abilities should be made. The students' aim of trying technological solutions was also to open up for design possibilities different from the existing driving simulator.

Figure 4.3. Virtual reality headset including a handheld driving wheel

Figure 4.4. Car racing game on a tablet

Figure 4.5. Laptop solution including a driving wheel attached to a table

The workshop participants got to try three technological solutions and evaluate their advantages and disadvantages. First, the participants tried a virtual reality (VR) headset which showed a movie clip of a rollercoaster. This was combined with a Wii steering wheel, i.e. a small, handheld steering wheel (Figure 4.3.). The steering wheel and VR headset were not connected in any way but was just something that the students wanted to test to see if such a combination could be useful. That is, the test persons could not steer what they saw

in the VR headset. Second, the participants tried a car racing game on a tablet (Figure 4.4.). Here, the participants were to steer the car on the screen by turning the tablet to the right and left, like a steering wheel. The third solution was a laptop with an open source driving simulator and a steering wheel attached to a table (Figure 4.5.). The participants referred to this as *the laptop solution*. The simulator included various tracks with roads, cars and driving environments and the participants could steer the car in the simulator with the steering wheel.

During the workshop, the participants explored these solutions and simultaneously reflected on and discussed them. The clinic often referred back to and compared the solutions to their old driving simulator. They thought that the laptop solution was the most suitable technology to use to assess patients, as will be elaborated in Part II of this chapter. After these initial meetings and workshops, the students worked on a prototype with the laptop solution, including tasks and instructions, which they tested by letting patients from the clinic try the prototype and by discussing it with the clinic. After improving the test further, the participants decided to evaluate the prototype in a pilot study in primary healthcare (see section 4.9.).

Accordingly, the design project resulted in further processes of evaluations and validity studies. However, as the aim of this thesis is to study why it is difficult to design innovative IT, the following sections of the chapter will focus on details in the design process. Hence, as Part I of this chapter has provided a background of the case including the participants, the old driving simulator, the context and the processes of the innovation contest and the subsequent design projects, it is now time to take a closer look at what was possible to design or not. This is done in Part II which focuses on possibilities, impossibilities and uncertainties in the design.

Part II – Identifying possible, impossible and uncertain designs

Part II focuses on the design of the new IT artifact, identifying possible, impossible and uncertain designs. Hence, this part is a result of the data-driven analysis of the empirical material (described in section 3.4.1. and 3.6.4.) and the questions that were raised from the observations, i.e. what designs are possible, impossible or uncertain and why? On what design matters do the participants seem to get stuck and why? Part II is not a comprehensive account of all of the identified possible, impossible and uncertain designs but consists of illustrative examples that can help answer the research question. Although this account is not comprehensive, it is still ample with a lot of details why every major section in this part ends with a box that provides a summary of the main points.

4.5. The challenge of assessing fitness to drive

A recurring discussion throughout the whole process, both during the contest and the subsequent design projects, concerned how fitness to drive should be assessed. The participants concluded that assessing a person's ability and fitness to drive was a complex

task. For instance, assessments could focus on a range of cognitive abilities, patients' judgment or risk assessment in traffic, their driving experience, personality or self-awareness, or if they could adapt their driving to their abilities. One of the VTI researchers argued that there is no clear definition of driving ability and consequently no established norm for how it should be assessed. Instead, he said that researchers in this area study people's potentials and preconditions to drive, focusing on the abilities that are essential for human beings to drive safely. The VTI researchers pointed out that it is not possible to foretell if people actually will drive safely even if they have the right preconditions. On the contrary, they argued that even unfit drivers have a fairly low risk of failing in traffic, especially if they adapt their driving to their impaired abilities.

The clinic and VTI researchers concluded that there was no established norm for how fitness to drive after brain injury should be assessed. Instead, the clinic focused on four cognitive abilities which they argued were relevant to assess since they have been shown to correlate with people's driving ability, but also because they can be compromised by brain injuries. These were 1) attention, 2) reaction, 3) simultaneous capacity and 4) processing ability. These abilities were not expressed in an orderly fashion (as this text may lead the reader to believe) but were gradually clarified and defined throughout the whole case during discussions and workshops. Since the following sections of the chapter focuses on the participants' attempt to design a test that measured the cognitive abilities, the abilities are briefly introduced below.

Attention and *reaction* were considered the most important cognitive abilities to assess, i.e. if the patients noticed stimuli or not and how fast they noticed stimuli:

You're supposed to be able to capture attention – that they pay attention, that attention is paid both ways [to the left and right] and how fast they pay attention. (Occupational therapist, 2015-02-11)

As indicated in the quote above, patients had to notice stimuli on both the left- and right-hand side. The clinic argued that this was important since some patients had problems detecting stimuli on one side due to one-sided brain injuries (described in section 4.7.2). *Simultaneous capacity* was an important ability as it is required in car driving to both keep the car on the road while simultaneously noticing and reacting to stimuli in the environment. It was also crucial that drivers quickly could process information and then decide how to react, i.e. to assess patients' *processing abilities*. The following sections describe how the participants tried to design a test that assessed these cognitive abilities and patients' fitness to drive.

4.6. Designing for ecological validity

One of the requirements, which the clinic called *ecological validity*, was that the test should resemble car driving (see Appendix B). The clinic found it problematic that many patients did not understand how their ability to drive could be assessed by tests that did not remotely resemble car driving. For instance, the clinic argued that the paper-and-pencil tests lacked a dynamic aspect which was needed in car driving, i.e. these test could not account for the

patients' reactions. The clinic had many stories about patients who did not understand why they had lost their driver's licenses. Some patients thought that the health professionals had become annoyed with them and thus retracted their licenses. Other patients blamed the tests for losing their licenses, e.g. that these did not have anything to do with car driving or that they did not resemble real car driving enough. Hence, the patients' experiences of the test was a crucial aspect, according to the clinic. Even though the clinic pointed out that agreement on the test results was not always achievable, they found it desirable that the patients understood and accepted the tests and that they felt treated fairly:

Many [patients] feel that it is questionable how they are treated. They have taken a simple cognitive test at a healthcare center and think "Does this have anything to do with driving?". Then, when they come to us and get a steering wheel, they feel much better: "Yes, but this actually has something to do with driving at least". They think that this is better – that they get to show what they can do. So, it's not insignificant, I think, in order to find that it's okay to be assessed like this. (Occupational therapist, 2015-03-30)

Ecological validity was frequently discussed in the case. Both the competing team and the students posed questions about how the requirement should be met. When was the test relevant or similar enough to car driving to make the patients understand and accept the test? The competing team suggested that ecological validity could be achieved by having health professionals inform and convince the patients about the relation between the test, the cognitive abilities and car driving. In this way, they thought that patients would understand what the test assessed and why impaired cognitive abilities were dangerous when driving. Consequently, patients were to find the test relevant. However, the clinic did not think that this would be enough to make patients understand and accept the test and the results:

This is what we do today. People have problems to understand even if they get information. (Occupational therapist, 2014-10-02)

The clinic argued that it was difficult to explain the rationality behind the test to the patients since many of them suffered from brain injuries that made it hard for them to take in and process such information. Instead, they pointed out that a steering wheel would make it easier for patients to understand that the test was relevant for assessing car driving abilities:

It becomes more grounded in reality with a steering wheel. It makes it easier for patients to understand that this has to do with car driving. (Occupational therapist, 2014-06-16)

The clinic argued that the steering wheel was essential because of its resemblance of a real driving situation, making the patients understand the test's relevance for car driving. Hence, a steering wheel was a key feature to achieve ecological validity in the test:

Student: Yes, but steering wheel was still a requirement from your side, it should be a...?

Occupational therapist: Yes, I think that's important...

Student: It doesn't have to feel like a car but there should be a steering wheel...?

Chief physician: That's what we call the ecological part in it. (2015-01-29)

4.6.1. Defining a realistic steering wheel experience

To come to a mutual understanding of when the requirement of ecological validity was met proved to be easier said than done. During the meetings and workshops, the students and clinic tried to define how ‘realistic’ or authentic the test and steering wheel had to be to fulfill the requirement of ecological validity – when was it relevant or similar enough to car driving? They did this by trying and discussing the different technological solutions in the workshop. This showed that not any type of steering wheel was possible to use in the test but that it had to have a specific design to meet the requirement of ecological validity.

For instance, when the clinic tried the car racing game on the tablet, they found this solution difficult. They had problems maneuvering the tablet since it could be turned in every direction – up, down, right, left, horizontally and vertically. It took some time for them to figure out how to use the tablet even though the students pointed out that they should hold the tablet in front of them and turn it as a steering wheel, not hold it horizontally in their laps. When they got a hang of this, the next problem was to use very small movements to turn, not to crash into a wall. The clinic thought that the tablet was difficult to steer and that it would take time for patients to learn how to maneuver the tablet. The main problem was that the tablet could be turned in all directions. Hence, a fixed steering wheel was preferred:

Student: What if the tablet is fixed?

Chief physician: If it's fixed, it becomes more like a steering wheel... (2015-02-11)

Furthermore, the chief physician also pointed out that it was unrealistic that the screen, i.e. what one saw on the tablet, turned as one was steering. He argued that it did not resemble car driving. In reality, turning the steering wheel does not turn the windshield. Hence, it was unrealistic that the tablet was both steering wheel and windshield:

The strange thing is that one is turning the screen at the same time as one is driving on the screen. It is a deviation from reality. (Chief physician, 2015-02-11)

During the workshop, the clinic also tried the VR headset and handheld steering wheel. They concluded that it was problematic that they could not see the buttons on the wheel, since they were encapsulated by the headset. Accordingly, the steering wheel would be more realistic if the patients could *see* the steering wheel since this would resemble a real driving situation.

As mentioned above, the clinic thought that the laptop solution was the most suitable technology to use. They argued that the laptop solution had ecological validity since this steering wheel would be easier for patients to learn to maneuver and understand than the other technological solutions. It was also pointed out that the laptop was very similar to the setup of the old driving simulator:

Student: But this solution is very similar to the one you have today?

The clinic staff: Yes.

Occupational therapist: But if you think of ecological validity, then this is very appealing. (2015-02-11)

In the laptop solution, the steering wheel was attached to the table which was considered more realistic than having a ‘floating’ steering wheel. This wheel could also only turn left and right – not in every direction. It was also more realistic as the steering wheel and the screen were separate (unlike the tablet) and that the patients could see the wheel (unlike the VR headset). Accordingly, the steering wheel of the laptop solution had many advantages compared to the other technological solutions.

However, a downside of the laptop steering wheel was that the clinic thought that it was very sensitive, which they found problematic. They said that patients often complained that the steering wheel of the old driving simulator was too sensitive – that turning the steering wheel only a little made the car turn a lot. This was deemed unrealistic by both the patients and the clinic, i.e. it was not similar to a real car driving situation. The students said that the wheel’s sensitivity could be adjusted and they experimented with making the steering wheel less sensitive. However, they found that when decreasing the sensitivity of the steering wheel, the driver had to make big wheel rotations to make the car move in the desired direction, even when driving on a fairly straight road. Both the students and the clinic thought that this was unrealistic. Hence, a realistic steering wheel sensitivity showed to be a delicate balance between too sensitive and too unresponsive.

4.6.2. Defining a realistic driving experience

It was not only the steering wheel that had to be realistic to achieve ecological validity, but the overall driving experience had to be convincing. When designing the test, a major question was how realistic the driving experience had to be and which features should be included and excluded to achieve ecological validity in terms of driving experience. The clinic acknowledged that, theoretically, the cognitive abilities could be assessed in a situation that did not resemble car driving at all:

This isn’t car driving. This is a dynamic way to test something else, we only use car driving to make it feel ‘car-like’. (Chief physician, 2015-02-25)

Hence, the test did not have to resemble an authentic driving experience in all respects. However, some features of the driving experience proved to be more important than others to achieve a realistic driving experience, as shown below.

Exclusion of car gear

Two important features of the driving experience were that the driver could view a road and that there was a feeling of forward movement on the screen since it would not make sense to steer a car standing still. This was indicated when the clinic tried the laptop solution:

This is not so strange... Nobody thinks it’s strange to sit and hold a steering wheel, have a gas pedal and watch the road. If you think of it in terms of ecological validity, it is quite uncomplicated. (Occupational therapist, 2015-02-11)

Initially, the clinic thought of including more than only the steering wheel, such as gas and brake pedals, but these and other car gear were eventually excluded. They argued that

pedals, gear stick, speedometer, rearview mirrors and so on would increase the test's complexity which would make it difficult to determine if the patients failed the test due to cognitive inabilities or difficulties to maneuver the car gear. Accordingly, the main goal of the test was to assess patients' cognitive abilities, not their abilities to maneuver pedals or other gear:

We're not interested in pedals for this particular solution since we're focusing on the cognitive parts.
(Chief physician, 2015-01-29)

Hence, even though the clinic argued that car gear could improve the ecological validity of the test and make it easier for patients to understand how the test related to car driving, these were excluded to make the interpretations of the test results less ambiguous. Some gear were also excluded since the test had to be adjusted to patients' physical impairments, e.g. patients in wheelchairs and patients who could only use one hand (elaborated in section 4.6.3).

A realistic traffic environment

The traffic environment also had to be realistic for the test to have ecological validity. This included what the driver saw on the screen, such as the scenery, details in the surroundings, oncoming traffic, and traffic rules and signs. This was a delicate balance between too unrealistic and too realistic. For instance, the car racing game on the tablet was considered too 'game-like' and unrealistic by the clinic. It was important that the patients did not feel that their driver's licenses were retracted due to a lost game. On the other hand, the scenery must not be too realistic and complex either. The clinic argued that the more complex the traffic situation, the more difficult to say exactly what was measured:

Well, the risk is... I mean... I think about how to interpret the results. It mustn't be too complicated for someone to draw a conclusion from it. If you add a complex environment, then there will be more aspects to take into consideration. I think it should be pretty clean so that you really know what you see [in the results]. (Occupational therapist, 2015-02-11)

Accordingly, a complex traffic environment would make it difficult to determine if the test assessed the patients' cognitive abilities or their capacities to e.g. interpret the traffic situation and act in accordance with traffic signs. Hence, even though a more realistic traffic environment could increase the ecological validity, a less realistic environment was chosen in favor of interpretability of the test results.

Traffic rules were also excluded, not only because it added to the complexity of the test, but also because patients could not act in accordance with the traffic situation. Since pedals were excluded, it was not possible to slow down when e.g. approaching crossroads or traffic lights and similar situations. Traffic rules were also excluded since patients who had not acquired their driver's licenses should be able to take the test. For instance, this could be underage patients with brain injuries who had to be assessed to determine if they met the medical requirements for driving. Hence, the test could not include traffic rules or other information that only people with driver's licenses knew. What was to be assessed was their cognitive abilities, not their knowledge on traffic rules.

How realistic the traffic environment could be was also restricted by the risk of motion sickness. When visiting VTI, the clinic had tried advanced simulators in which they all had become nauseous. As motion sickness would be a problem when assessing patients, the clinic was concerned about this risk. According to them, one reason why motion sickness occurred was if the driving experience was too realistic:

It depends on the... how realistic the setup is. It's not a problem when it's stylized, very simple, but if it's very virtual, like an experience of sitting and driving a car, then it will have that effect. (Chief physician, 2015-01-29)

The clinic staff also got motion sick when trying the VR headset. They thought that it felt a little too real. The chief physician pointed out that in order to avoid motion sickness, they had to find a compromise concerning how realistic the test should be:

We have to find a compromise. The more realistic it is, the greater is the concern with nausea. (Chief physician, 2015-02-11)

The clinic argued that lifelike and realistic surroundings with e.g. lots of trees on the sides of the road could cause motion sickness. They compared this to the simple and stylized traffic environment of the old driving simulator (Figure 4.6.) in which patients did not become nauseous. Hence, the traffic environment could not be too realistic nor unrealistic. Once again, the laptop solution was considered most appropriate since it included a track with a simple scenery with a fairly straight country road and mountains in the horizon (Figure 4.7.). The clinic thought that this scenery was a good environment since it did not contain a detailed surrounding and, thus, would not cause motion sickness but still resembled car driving satisfactorily. As indicated in Figure 4.6. and 4.7., the design of the old and new test were fairly similar.

Figure 4.6. Traffic environment of the old driving simulator

Figure 4.7. Traffic environment of the laptop solution

Another aspect that was deemed positive by the clinic was that the laptop solution could visualize the car on the screen (see Figure 4.7.). This was something that the old driving simulator lacked and that both patients and occupational therapists criticized. The patients found it strange that they could not see the hood of the car and, hence, did not know how well they kept the car on the road. However, when discussing this with one of the VTI researchers, it was pointed out that in reality, drivers do not see the hood when driving

modern cars. Thus, visualizing the hood of the car increased the ecological validity, according to the clinic, as it helped the patients understand and accept the test, even though it did not accurately mimic a real driving situation.

4.6.3. Adjusting the design to the patients

Another aspect of ecological validity was the patients' experiences of the technology. The clinic often described the patients as confused, worried and scared due to e.g. dementia and old age. This had implications for the kind of technology they considered appropriate for the patients, in order for them to understand and accept the test. For instance, the clinic was not sure how the patients would react to the VR headset. They feared that patients would find it strange and frightening since many patients were intimidated by the existing driving simulator:

The only thing I'm a little worried about is the older patients. They become frightened when they see a computer screen. They will be terrified when they see this [VR headset]. (Occupational therapist, 2015-02-11)

The clinic also found it problematic that the patients would be encapsulated by the VR headset. As mentioned above, the headset created a realistic feeling and, consequently, the patients could become scared by it. The clinic pointed out that the strangeness of the technology may result in a higher threshold for patients to understand and, thus, accept the test, which would inhibit ecological validity. They pointed out that this might not be a problem with younger patients but that most of their patients were of old age.

That the patients would be encapsulated by the headset was also a negative feature as it would mean that the health professional would not be able to help the patients and follow what is happening in the test. One of the occupational therapists said that many patients needed help and support to understand the tasks of the old driving simulator. Accordingly, the test's ecological validity would increase if the health professional could see and follow the test during the patients' performances and, thus, help the patients to make them understand the test.

As mentioned above, the test also had to be adjusted to patients' potential physical impairments. Since the test was about assessing cognitive abilities, the patients should not fail the test because they had problems maneuvering various control gear. Pedals were excluded because patients in wheelchairs should be able to take the test. Gear stick and other car gear were also excluded since it should be possible to maneuver the test with only one hand. That is, patients who have been subjects to stroke or other brain impairments may suffer from loss of motor skills, e.g. paralysis or weakness in the right or left side of the body and/or loss of coordination of muscle movements. This meant that the test and the steering wheel had to be designed with these physical impairments in mind (as stated in the requirements, see Appendix B), i.e. that the patient should be able to maneuver the test with one hand only. Accordingly, car gear such as pedals and gear stick were not *only* excluded due to that these would increase the complexity of the test, making it difficult to

assess if patients' had the cognitive abilities to drive or not, but also because the test had to be adjusted to patients' physical impairments.

The requirement that the test should be maneuverable with only one hand also entailed other design constraints. For instance, the tablet was ruled out since patients would have difficulties holding and maneuvering it and simultaneously pressing buttons on the screen to react to stimuli. This was also another reason why the clinic found it important that the steering wheel should be *fixed* – it would make it easier to maneuver with only one hand.

Even though the participants found the laptop solution to be the most suitable technology, there were also some disadvantages with the laptop steering wheel. The clinic compared this wheel to that of the old driving simulator, where the buttons were symmetrically located 'ten-to-two' on the front side of the wheel's rim, which made them easy to see and reach with the thumbs when steering (see Figure 4.8.). Patients who could use both their hands pushed the button on the right-hand side with their right thumb and the button on the left-hand side with their left thumb. Patients who could only steer with one hand, e.g. their right hand, used the two buttons on the right-hand side where the button furthest to the right, labelled '1', was pushed when arrows pointed to the right and the button on the left, labelled '3', was pushed when the arrows pointed to the left. Patients who could only use their left hand used the buttons labelled '2' and '4'. This enabled these patients to both steer and react simultaneously.

Figure 4.8. Steering wheel of the old driving simulator

Figure 4.9. Steering wheel of the laptop solution

The laptop steering wheel, on the other hand, had a lot of asymmetrically placed buttons on both the front and back of the wheel which were hard to reach (see Figure 4.9.). The students had difficulties finding buttons that were both easy to see and reach while steering, that were not tough or stiff to push and that suited both patients who steered with two hands and one hand. The only symmetrical and reachable buttons were located on the backside of the wheel but these were ruled out because these would be more difficult to

understand as the patients could not see them and they were also rather stiff which would be a problem for patients with weak hands. Due to this, the students adjusted the prototype so that patients were to react to stimuli by pressing the button labelled '□' for arrows pointing left and the button labelled '○' for arrows pointing right. This meant that all patients were to react using their right hand and, hence, the prototype was somewhat limited by the setup of the steering wheel. That is, this inhibited patients who could only use their left hand from taking the test properly. The students said that they had preferred a symmetrical steering wheel as this would have made it easier to accommodate both left- and right-handed patients.

4.6.4. Summary of designing for ecological validity

Above, many examples of possible and impossible designs in terms of ecological validity, i.e. that the test resembled car driving and made the patients understand and accept the test, have been given. The main points are summarized in Box 4.6. on the next page.

4.7. Designing the test tasks

Although ecological validity was an important aspect of the design, the core aim of the test was to assess cognitive abilities. However, exactly how the test should measure these abilities was a key discussion when designing the test tasks. The tasks in the new test were similar to the old driving simulator, at the clinic's request. The tests were divided into two types of tasks – a *primary task* and three *secondary tasks*. The primary task was to steer a car on a road to achieve a cognitive load (elaborated in the next section). In the new test, the secondary tasks included various assignments that the patients were to perform while steering the car, i.e. to react to stimuli in different ways. The following sections describe possible and impossible task designs.

4.7.1. Designing a primary task to create a cognitive load

As mentioned in section 4.2.1., the primary task in the old driving simulator entailed that the patients should keep the car on the road while compensating for simulated wind. The clinic explained that this task had to be a bit difficult so that the patients needed to focus and pay attention to perform the task successfully. By performing this task, the patients were exposed to a *cognitive load*, which was essential in order to detect certain brain impairments, e.g. if patients started to react slower or missed stimuli when under pressure. Based on these arguments, the clinic wanted the new test to include a primary task too.

Box 4.6. Summary of designing for ecological validity

- It was crucial that the test had ecological validity, i.e. that it resembled car driving, to make patients understand and accept the test and the test results. Tests that did not resemble car driving were not considered possible since they would not convince patients that their ability to drive was assessed.
- By including a steering wheel, the test would resemble car driving. The steering wheel had to have a specific design to meet the requirement of ecological validity, rendering some designs impossible and others possible. For instance, the steering wheel had to be realistic and easily maneuverable.
- Ecological validity was also achieved by designing a realistic driving experience. However, how realistic the driving experience could be was limited by that the test could not be too complex since this would make measurements ambiguous. Neither could the test be too realistic since this could make patients motion sick or unable to maneuver the test due to physical impairments.
- To achieve ecological validity, it was possible to design a simple and stylized traffic environment where the patients saw a road and experienced a feeling of forward movement on the screen. It was also possible to visualize the hood of the car even though this was not a realistic driving experience but it helped the patients understand how well they kept the car on the road.
- The design also had to be adjusted to the patients. Here, impossible designs included intimidating technology and encapsulating the patients since this would hinder them from taking the test to the best of their abilities. This also hindered the health professionals to help and instruct the patients during the test.
- Possible designs included less intimidating technology where the patients were not encapsulated but where both patients and health professional could see the screen, enabling the health professionals to help and instruct the patients during the test.

Using curves for the primary task

During the design project, the students and the clinic discussed ways to create cognitive load without using simulated wind. The students pointed out that the wind, which made it difficult to keep the car on the road, was not very realistic:

It is not very logical that the car just flies away (waves her hand to show how the 'wind' sweeps the car off the road). (Student, 2015-02-11)

The students proposed using a curvy road as this would make it more realistic and, thus, increase the ecological validity. The clinic thought that this was a good suggestion:

Chief physician: The way that *that* version felt like (points to the laptop), then I think curves are quite sufficient to increase the difficulty.

Occupational therapist 1: I think so too.

Occupational therapist 2: Mm.

Chief physician: It requires concentration, you have to make sure you are within your lane without crossing the line. (2015-02-11)

Accordingly, a curvy road seemed to be a viable option since it required concentration and effort and, thus, created a cognitive load. There was, however, a limit to the curviness of the road. As mentioned earlier, motion sickness was a risk and in the clinic's discussions with the VTI researchers, it was concluded that sharp curves often tended to cause motion sickness. This made the clinic cautious about adding too many curves to the test as it would be impractical if patients became motion sick since this would prevent them from taking the test and perform at their best. Hence, the risk of motion sickness limited how curvy the road could be.

Using velocity to increase and individualize the cognitive load

The clinic emphasized that the primary task had to be demanding enough to create a cognitive load for each and every patient. One of the occupational therapists pointed out that there was a difference in how well patients managed to perform the primary task. She argued that the clinic had a diverse group of patients where younger patients might not be challenged by a non-curvy road and a slow speed, whereas this would be enough to create a cognitive load for older patients. Accordingly, a disadvantage of using curves to create a cognitive load was that it was difficult to adjust the level of difficulty to different patients:

I think that *that's* a little more difficult with this, because it varies a lot. A young person who has played some computer games may be more alert. In this solution, the difference won't be so big – it will be the same difficulty for all patients. Today, everyone is challenged with an individualized amount of wind. I usually say to patients that “It's supposed to be a bit difficult, you should have to make an effort, everyone should, because that's needed when driving a car”. (Occupational therapist, 2015-02-25)

Also the chief physician emphasized the importance of making the primary task difficult for every patient:

It's good if we can increase the difficulty so that we can push even those who are really good. Ideally, everyone should find it a little difficult. (Chief physician, 2015-01-29)

As the test had to encompass different levels of difficulty to create a cognitive load for every patient, the students suggested that the speed of the car should be variable since the same curviness would be more difficult with a higher velocity. The clinic thought that speed was a good way to adjust the difficulty. It made it possible to slow the test down if the patient had troubles or speed it up if it was too simple. Hence, changing the velocity was deemed to be a feasible way to increase or decrease the level of difficulty. However, the clinic did not know exactly how difficult they had to make the primary task for it to become a cognitive load for every patient. They argued that they had to evaluate the levels of difficulty empirically:

We need to see people drive this to get an idea of what's a difficult level and what's not. (Chief physician, 2015-04-27)

Another important aspect that had to be evaluated empirically was the duration of the test. The written requirements stated that the test should capture patients' abilities to concentrate over time (Appendix B). One of the occupational therapists said that some patients managed to concentrate for a while under cognitive load but then got tired and started to make mistakes or react slower. Hence, it was important that the test was not too short. However, exactly how long the test should be to account for concentration and cognitive load was uncertain. The clinic made several different estimates ranging from 6-30 minutes. They referred to the old driving simulator which took about 30 minutes to complete. The clinic found it difficult to determine the duration of the test, indicating that there was a lack of knowledge about how to determine the difficulty and duration of the test in order to create a cognitive load. Hence, exactly what was 'difficult enough' or 'long enough' was left open and had to be evaluated empirically. In their prototype, the students made every task 2-3 minutes long, but argued that this was easily adjusted if it was too short or long.

4.7.2. Designing the secondary tasks

When designing the secondary test tasks, the clinic and students discussed what the test tasks should include, e.g. what the patients should do and what stimuli should look like. At the clinic's request, the tasks were to be introduced one at a time, as in the old driving simulator. Hence, a similar approach was to be used in the new test where the primary task was introduced first, followed by the three different secondary tasks, sequentially. The patients were to perform the same primary task during all the secondary tasks, i.e. drive on the same road.

Test tasks and what stimuli should look like

The first secondary task entailed that the patients were to react to whether stimuli was on the right-hand or the left-hand side of the road by pressing corresponding buttons on the steering wheel as quickly as possible. This assessed the patients' attention and reaction. In the second secondary task, the patients were to discriminate between the directions of the arrows regardless of which side of the road they appeared on, i.e. it required the patients to process what they saw and make a correct decision on how to react. Hence, this task aimed at assessing both attention, reaction and processing ability.

When designing the second secondary tasks, the question was raised what stimuli should look like. Rather than using two different shapes or colors, as suggested by the students, the clinic preferred if stimuli resembled traffic signs:

Chief physician: Then we could use some kind of arrow signs. A sign is not so bad in this context, right?

Student: Like a traffic sign?

Chief physician: Yeah, a traffic sign with arrows pointing to either the right or left.

Student: Like the test in the basement [the old driving simulator]?

Chief physician: Mm, yeah. (2015-04-27)

The students suggested that stop signs and warning signs could be used since these would be easier to tell apart than signs with arrows. These would still add to the test's ecological validity by resembling a traffic environment. However, the chief physician pointed out that it was supposed to be quite hard to tell the arrows apart since this would demand of the patient to process what they saw. Accordingly, it was not possible to change the design of the stimuli since this would change the second secondary task. This entailed that the students designed stimuli that looked like yield signs with arrows. In this sense, both the second secondary task and the stimuli were essentially the same as in the old driving simulator.

The third secondary task also measured processing ability. Here, the patients were only to react when the arrow pointed to the right. This meant that they had to suppress a reaction when arrows pointed left. The clinic wanted to include this task to see if patients could process stimuli and then choose *not* to react to all stimuli. It was argued that it was harder *not* to react than to react:

Chief physician: Then you are testing the ability to refrain from reacting. It is much easier to react as soon as something happens. But if things happen and sometimes you have to single out "I will not respond to *that*" and "I will react to *that*" – it becomes an extra loop (points towards the brain).

Occupational therapist 1: A processing...

Occupational therapist 2: The mind processes... (2015-02-11)

Hence, it was important that the patient had to distinguish between when to react or not. This task did not exist in the old driving simulator but differed from the old test.

Where to present stimuli

A recurring topic in the students' and clinic's discussions was where stimuli should be presented, i.e. at what angle they should be positioned. The students wanted to know what specific angles were needed since this affected the design of the test, e.g. how wide the screen had to be or if more than one screen was needed. The clinic was not sure what angles were appropriate but argued that what was most important was that stimuli were not positioned in the central visual field but in the peripheral field of view. However, it was difficult for the participants to come to a shared understanding of why this was important.

The students' interpretation of this was that stimuli had to be presented in the peripheral field in order to test the patients' peripheral vision. They suggested that peripheral vision could be tested manually by holding up two fingers on the sides of the patients and slowly moving the fingers from the periphery to the central visual field until the patients noticed them. However, the clinic clarified that patients' peripheral vision should be examined before coming to the specialist clinic and that patients who did not meet the criteria for peripheral vision were not to be assessed by the clinic since their impaired vision disqualified them as fit drivers.

Instead, the reason why the clinic emphasized that stimuli should be put in the peripheral visual field was because this enabled them to assess potential one-sided brain injuries and distinguish between how well the cerebral hemispheres processed stimuli:

That's because the brain processes the left and right fields of view in different parts of the brain. So it is not certain that it is processing the right visual field just as fast as the one that processes the left. (Chief physician, 2015-02-11)

Hence, to present stimuli in the central field of view was problematic since both hemispheres processed that information. But if the angle was wider, then it was possible to separate if stimuli was processed by the right or left hemisphere. This would make it possible to assess if there were attention, reaction and/or processing deficiencies in the right or left side of the brain.

To exemplify such an injury, the clinic described the condition *neglect* in which one side of the brain fails to process information properly. That is, a person can have perfect vision on both eyes, but react slowly or not at all to stimuli on the left-hand or right-hand side, due to a brain injury. This means that stimuli are registered by the eyes but that the information processing is deficient, resulting in that the patients may not understand what they see or how they should react to it:

Then it's [the stimulus] registered. The primary cortex has seen it and in a neurophysiological sense you have seen it, but it takes too long for you to understand that there is something there and for you to take it into account. (Chief physician, 2015-02-11)

The clinic explained that this condition can be more or less severe. In severe cases, patients do not register stimuli on one side even without or with a low amount of cognitive load. For other patients, the inability to register stimuli only occur when under a cognitive load, meaning that they notice stimuli when they focus on one task only, but miss stimuli when a second task is added, i.e. when the cognitive load increases. Another indication of neglect is that patients are slow in detecting stimuli, as it takes longer for one of the hemispheres to process the information, due to the brain injury:

The gradation has to do with how severe the lack of reaction is, so to speak. This can range from being slow – if it is a small injury you might be a little slow and lose some [information] – and if it is a severe injury, it may end up with that you don't notice anything at all. (Chief physician, 2015-02-11)

This meant that the clinic was not interested in testing peripheral vision but that the peripheral angles were a condition to discriminate between the hemispheres and to identify potential cognitive deficiencies due to one-sided brain injuries.

Uncertainty about angles and brain injuries

Despite the clinic's explanations, the students' question about specific angles for the test remained. The clinic was not sure exactly what angles were needed to assess this type of brain injury. Initially, they decided to go with the requirements in the traffic constitution which stated that drivers should have a visual field encompassing 120 degrees:

In terms of the visual field, there are very carefully calculated angles in the [traffic] constitution, but this is not so much vision we're after, but one can probably use those angles anyway, I think. (Chief physician, 2015-01-29)

However, the chief physician later questioned if it really was necessary to have such a wide angle as they initially had stated. Instead, he argued that they had to be cautious about placing stimuli in the central visual field as this would entail that both hemispheres processed stimuli, making it impossible to separate the two hemispheres:

Chief physician: But I feel a little unsure of it if it's useful to put stimuli at the far end of the field of view. We're not looking to test the visual field.

Occupational therapist: No.

Chief physician: We want to catch the right and left hemisphere, how they process stimuli. To be sure that you really are there [in the peripheral view], so you're not in this central visual field.

Student: Exactly.

Chief physician: So one could probably be able to put stimuli at about 30 degrees, I think that would be a practical and perhaps a reasonable angle to use. (2015-02-11)

The chief physician argued that using a 30-degree angle would be enough to distinguish between the two hemispheres. This was an estimate and the clinic was not sure if there was research to underpin this but argued that if they avoided the central field of view, then the test would account for the different hemispheres:

Nobody really know this, but I think that if we use 15-30 degrees, then I think we can relax. (Chief physician, 2015-02-11)

The uncertainty and lack of knowledge about the exact angles relevant for assessing neglect and one-sided brain injuries led to these estimates and also that they chose to mimic the old driving simulator. The clinic estimated that the old driving simulator had a 30-degree angle and that this angle made it possible to distinguish between the right and left side of the brain and thus detected potential side differences in attention, reaction and processing ability. They also maintained that the main point was that stimuli were not presented in the central visual field but in the peripheral visual field.

Specifying angles, distances and fixtures

The 30-degree angle was also discussed in relation to the technological solutions in the workshop. The clinic did not think that the tablet was wide enough to assess side differences in the hemispheres. Similarly, the laptop screen was considered too narrow but this could be compensated by using one or several larger external screens. The clinic thought that the VR headset was better than the tablet since it had an angle of approximately 100-110 degrees. However, as mentioned above, this had other disadvantages. Again, motion sickness was brought up as a potential problem. The clinic argued that having a very big screen or being encapsulated by the headset could lead to motion sickness. They said that nausea was more likely to occur with a big screen since it covered a major part of the visual field, resulting in that the patients lacked a fixed point of reference in the room:

Chief physician: As long as you have fixed points of references, it works.

Occupational therapist: Exactly, you can see the walls around you.

Chief physician: If you lose your reference point, then the brain thinks that you're moving...

Occupational therapist: But I stand still.

Chief physician: ...but your semicircular canals do not detect any movement so the brain sends a warning. (2015-02-11)

The chief physician argued that when one could keep the points of reference, being aware of one's surroundings, then the brain was not 'tricked' and, hence, no motion sickness occurred. In this sense, even though the clinic had concluded that the screen must not be too narrow, it should not be too big either. They thought that the laptop solution had clear points of references and thus that the risk of motion sickness was low. Hence, the screen width both had to account for the right angle in order to assess the hemispheres but also avoid motion sickness.

Although there were many different explanations about what caused motion sickness, the VII researchers argued that knowledge was lacking about exactly why motion sickness occurred. Understanding motion sickness was much more complex than if one had fixed reference points or how realistic and curvy the test was. The researchers said that it was hard to predict which simulator scenarios would cause nausea. They described examples in which drivers became less motion sick when moving closer to the screen, counterintuitive to the idea of having clear reference points, and scenarios without curves in which people became nauseous. The clinic concluded that it was important for them to avoid motion sickness in the test but that there was no straightforward way to know if and when it would appear and that they had to test empirically what worked or not.

Another aspect of finding the right screen size and angle to assess one-sided brain injuries was the distance between the patient and the screen. That is, if the patient would sit far away from the screen, the angle would be narrower and vice versa. For this reason, the chief physician and the students spent quite some time calculating angles of the various technological solutions during the meetings. For instance, they calculated how big an external screen to the laptop solution had to be and how far away from the screen the patient had to sit to cover 30 degrees. The calculations were also important to make sure that the setup was the same for all patients in terms of distance to the screen, otherwise the angle would change with the risk of presenting stimuli in the central visual field. The clinic suggested a 'fixture' to make sure the test was mounted properly every time to ensure that the angles would be correct. This could be marks on a table which indicated where the laptop, screen and steering wheel should be positioned. Hence, the setup had to be fixed to ensure that they were measuring the cognitive abilities accurately.

Despite these discussions, the participants never settled for a final screen size and distance. In their Master thesis, the students argued that it was outside the scope of their study to determine the degrees needed to assess these types of brain injuries. Instead, they acknowledged that using the rather small screen of the laptop was a simplification and that more or

wider external screens probably were needed to present stimuli in the patients' peripheral visual fields. They concluded that the placement of stimuli needed further investigation.

In summary, in the participants' endeavor to design the test task, several details had to be taken into account, ranging from the design of the road, the speed, the stimuli and the screen width, to mention but a few. Another important aspect was to let the patient practice before taking the test, as described in the next section.

4.7.3. Practicing on the tasks before taking the test

When designing the test tasks, the clinic emphasized that it was important that patients could practice on the tasks before taking the test, which also was an explicit requirement (see Appendix B). Practice was important for several reasons, according to the clinic. When the patients practiced to keep the car on the road, they became familiar with the setup and tasks, e.g. got a feeling for the steering wheel and the steering sensitivity (see section 4.6.1.). Practice also contributed to that the patients understood the test and what they were supposed to do. Especially older patients needed practice, according to the clinic. This was important since the patients should get the opportunity to perform at their best:

Occupational therapist 1: They're not supposed to miss stimuli because they didn't understand the task.

Occupational therapist 2: No, because then we don't really know what we see. Was it that they didn't understand what they were to do? (2015-02-25)

The clinic argued that practice parts in the test were desirable to make the test results interpretable – did the patients miss stimuli because of lack of attention or because they did not understand the task? The occupational therapist who conducted the test with the patients said that many patients had difficulties understanding her instructions about the test and that they only understood the task after they had gotten the chance to practice. For instance, in the old driving simulator, the patients found it hard to understand the task in which they were to push in the direction of the arrows, not if the arrow appeared on the left or right screen:

Today, the patients get to try the simulator for two minutes and that's pretty good really, because if you think about the older ones who aren't used to... It's good that they get acquainted with the task. And many of them have difficulties to understand when I explain "Now, when the arrow points to the... and you are to [push] in the direction of the arrow..." And it's still not obvious once they start pushing, many have great difficulties with it, they do not really understand: "Ooh, was it like *that!*? Ahaaa! *Now* I get it!". They understand after a while and then it's good that they get to practice. (Occupational therapist, 2015-02-25)

The clinic preferred if the new test included flexible practice parts that could be adjusted by the health professional if they thought that the patients needed more practice to understand the tasks or learn to maneuver the steering wheel. Hence, practicing before taking the test was supposed to help the patients understand and accept the test.

4.7.4. Summary of designing the test tasks

Above, many examples of possible, impossible and uncertain designs of the test tasks have been given. The main points are summarized in Box 4.7.

Box 4.7. Summary of designing the test tasks

- The design of the tasks in the new test were in many ways similar to the old driving simulator. In the process of designing the test tasks, several impossible, possible and uncertain designs were identified.
- When designing the primary task, which aimed at creating a cognitive load for the patients, the task design had to contribute to the ecological validity but not make the patients motion sick since this would prevent them from performing their best. Hence, a moderately curvy road was chosen.
- The participants did not know how difficult or long the test had to be for every patient to experience a cognitive load and potential fatigue. Due to these uncertain designs, they argued that these matters had to be evaluated empirically.
- The design of the secondary task was similar to the old driving simulator. Although there were other suggestions about what stimuli should look like, it was not possible to change this design since the arrows should be demanding enough for the patients to process.
- The clinic was uncertain about how wide the screen had to be and, thus, mimicked the traffic constitution and the old driving simulator. Here, it was impossible to have a too wide screen since this could cause motion sickness but it was also impossible to have a too narrow screen since this would make it impossible to separate the hemispheres and, thus, it would not be possible to identify one-sided brain injuries.
- By including flexible practice parts in the test, this would enable the health professionals to adjust the amount of practice to every patient until they deemed that the patient could maneuver and understand the test.
- Practice also increased the test's interpretability since it made it easier to assess if the test results were due to cognitive impairments or due to inability to maneuver the wheel or understand the instructions.

4.8. Designing the test results

Another important aspect of the design was the test results. The report of the old driving simulator consisted of a sheet of paper with tables of numbers showing the patient's results. The numbers in the report included level of difficulty achieved, measures of reaction time, incorrect responses, missed stimuli and also a measure indicating how much the patients were reeling from side to side on the road. The clinic argued that the new test had to register similar measures but that these also needed to be presented in a more pedagogical way. The

following sections describe how the cognitive abilities were to be measured, followed by descriptions of how these measures should be interpreted, validated and presented.

4.8.1. Measures of the cognitive abilities

Most of the measures of the cognitive abilities in the new test were similar to that of the old driving simulator. The new test had to measure how many stimuli patients noticed, i.e. how many times they pressed the correct button when noticing a stimulus, as this indicated the patients' abilities to pay attention and react. Correct responses showed that the patients had noticed the stimuli – they had paid attention. The test also had to register the reaction time of the patients' responses. This was considered a measure of their ability to react and how fast they paid attention. This was also an indication of their ability to process information, i.e. if the patients managed to process information quickly or slowly.

The clinic also wanted the test to register the amount of missed stimuli. This measure showed if the patients did *not* notice stimuli which indicated that the attention of the patients were impaired and/or that they were too slow in their reactions, e.g. due to impaired processing ability. Furthermore, the clinic thought that it was important to know how many incorrect responses the patient made, e.g. if the patient pressed the left button even though the stimulus appeared on the right-hand side:

Today, with the old driving simulator, there are a lot of patients who just push. They don't manage to press in the direction of the arrow, so they just push all the time as soon as a stimulus shows up. And then you can see that they react but they don't manage to distinguish between different stimuli. (Occupational therapist, 2015-02-25)

The clinic argued that these incorrect responses indicated that the patients had troubles to process what they noticed, make the correct decision and respond accordingly. This also included incorrect responses such as pushing a button even though they were to suppress a reaction (the third secondary task). This indicated that the patients had problems in processing information and make decisions in accordance with the test instructions.

It was also important that the report showed potential side differences, i.e. that it made a distinction between left-hand and right-hand stimuli in order to indicate if the patients' attention was insufficient or reactions were slower on one side, indicating a one-sided brain injury (as explained in section 4.7.2.). If the patients missed many stimuli or had slower reactions on one side, this implied that one hemisphere did not process stimuli properly or processed the information slower, indicating lack of attention or a slow processing ability in one hemisphere.

Furthermore, the clinic also wanted a measure for how well the patients managed to perform the primary task. They suggested that the test should register every time the car crossed the road markings, indicating that the patient reeled from side to side. This would produce a measure of patients' ability to keep the car on the road. The clinic also thought that it was important that the results showed the patients' performances over time to detect if patients started to make mistakes, miss stimuli, drive worse or become slower in their

reactions due to fatigue or lack of concentration. This indicated that patients' cognitive abilities deteriorated after being subject to a cognitive load for a longer period of time, indicating that the brain did not manage to register stimuli correctly when being under cognitive load. The students also suggested that the results of the primary task could be illustrated graphically (described in section 4.8.3.).

Apart from attention, reaction and processing abilities, the clinic also wanted to assess the patients' simultaneous capacity. As noted above, performing the primary and a secondary task at the same time indicated simultaneous capacity. Hence, the measures for attention, reaction and processing ability were also indications of the patients' simultaneous capacity.

4.8.2. Including norm data to make the results interpretable

The numbers in the report of the old driving simulator were interpreted in relation to a standard provided by those who had developed the test. This was a sheet of paper that specified what numbers the health professionals should look at and what intervals the patient should stay within, i.e. what was considered normal performances. The clinic required that also the report of the new test encompassed comparative values (norm data) to make the results interpretable (Appendix B). That is, there had to be a standard or norm to which patients' results could be compared. Without this, what was considered 'normal' or 'deviant' would be ambiguous. Comparative values, or norm data, were frequently discussed. For instance, exactly what was required of a driver in terms of cognitive abilities was unclear. When designing the test results, the students wondered where the clinic would draw the line for how much a patient were allowed to reel when steering. The clinic replied that there did not exist any clear thresholds discriminating between those who were fit to drive or not, since it was a new test:

Student: Because you have no strict requirements for how well one has to do?

Occupational therapist: No, there's no evidence on exactly what one should be able to do or not when it comes to this. Especially not when it is something new. (2015-01-29)

The clinic pointed out that values for what test results were normal or not was something that they had to develop themselves – there were no pre-existing norm data that they could use. Instead, the clinic argued that they needed to test 'normal' people of different ages to see how they performed on the test, to have something to compare the patients to:

We need to run the test with those who are good and bad until we see approximately how they are distributed. (Chief physician, 2015-03-30)

For instance, when discussing the level of difficulty to create a cognitive load, the clinic found it difficult to know what was a reasonable level in the test, e.g. how difficult the test had to be to make sure that every patient had a cognitive load (as mentioned in section 4.7.1.):

Occupational therapist 1: I think it's difficult to know what's a good level.

Chief physician: We don't know that.

Occupational therapist 2: That's what we have to test later.

Chief physician: It's the next step.

Occupational therapist 1: Yeah, but I mean, we may have to change after a while. Or we find that "no, but this was too easy".

Occupational therapist 2: And then when we think we are at about the right level, then we have to run reliability studies.

Occupational therapist 1: Yes, we have to do that. Use it and collect data.

Occupational therapist 2: To see what's normal. (2015-02-11)

The chief physician pointed out that the test had to be validated so that they knew where boundaries for normal and deviant lie. Both the clinic and the researchers from VTI pointed out that it was important to finish the design of the test before creating norm data. The researchers from VTI recommended that the clinic should calibrate the simulated scenario until they were satisfied with it before creating norm data for the specific scenario. This was important since, if changes of the scenario were made after creating the norm data, then this would make the norm data invalid. Hence, the scenario had to be fully developed and 'fixed' for norm data to be valid, which made creating norm data a later process. To conclude, the clinic needed to build a norm databank for the specific test since this did not exist beforehand.

Comparing the old driving simulator and the new test

Another way to calibrate the new test and assess its validity and reliability, suggested by the clinic, was to run the new test in parallel with the old driving simulator. That is, patients were to take both the new and old test when being assessed. In this way, the results could be compared. According to the clinic, this would help interpret the results from the new test, using the old simulator as a guideline. However, as the clinic had not been part of the development and validation of the old driving simulator, they did not know what the norm data of the old driving simulator were based on. That is, it was unclear how the values of normal performances had been established. Hence, they did not know exactly what they compared the new test to.

Furthermore, the clinic pointed out that the results of the old driving simulator may not always be precise due to the worn-out equipment. One of the occupational therapists said that some of the buttons on the steering wheel were 'glitchy', i.e. there were loose connections which sometimes resulted in a delay:

We have a little problem with this right button because it's so worn-out, so I always say to the patients that "You have to press the right key a little distinctly for it to work". (Occupational therapist, 2015-03-30)

This was especially problematic for patients with weak hands or lack of coordination. They experienced the buttons as tough or stiff, making them difficult to push, which affected their response times. Hence, the measurements of the patients' reactions were not always exact since they sometimes had to press the same button twice for the simulator to register their response. The occupational therapist said that she tried to take this delay into account in her observations, but that it was problematic since the test was supposed to show

potential sides differences in the patients' responses. With the worn-out right button, there was a risk that a difference occurred that was due to the button and the strength of the patients' hands, rather than because of a cognitive impairment or one-sided brain injury.

4.8.3. A pedagogical report to create understanding and acceptance

In addition to the measures of the cognitive abilities described above, the report of the new test also had to present the results in a more pedagogical way. Both the clinic and students agreed that the report of the old driving simulator was difficult to read and understand for someone who was not familiar with it, i.e. to know what the numbers meant and how they should be interpreted. Accordingly, the clinic thought that the report should have a more intuitive design. This was also stated in the requirements, i.e. that the report should present test values numerically and graphically (Appendix B).

The clinic wanted the report to be pedagogical as they found it important that patients understood how they performed on the test. With the old driving simulator, the occupational therapist could only tell the patients about their performances, hence, feedback was only possible through the therapist's observations and explanations of how the patient steered and reacted:

I don't have any good way to show it, but I can say [to the patient] "I saw that you were slower on... [one side]". I meet most of the people one more time [after the test occasion] and then I usually have summarized their test results but it's not exactly optimal. (Occupational therapist, 2015-03-30)

A more pedagogical report could help health professionals explain and make the patients understand if they were fit to drive or not and, thus, why they got to keep their driver's licenses or not. This was important since losing one's driver's license may have a great impact on people's lives. However, as mentioned in section 4.6., explaining to patients that they were not fit to drive was not straightforward due to the brain injuries. Therefore, it was important that the report could function as a communication tool to help health professionals explain the results to patients. This was to raise the patients' awareness of their cognitive (dis)abilities and, thus, help them accept the results. Accordingly, patients had to find the results comprehensible, relevant and reliable in order for them to both understand and accept the outcome of the test.

Visualizing the results

Since it was important that the report was easy to understand, several ideas came up on how to accomplish this. The clinic thought that one way to make it easier for patients to understand how well they did on the test, was to present the results graphically, e.g. through bar charts or normal distribution graphs to visualize results and comparative values. The clinic argued that such a visualization would be good for the dialogue with the patient, to show how the patient performed compared to others in the same age:

You had some good ideas of how to show the patient's achievement in a pedagogical way, so to speak. That you can somehow see the normal distribution and where they ended up. It's a strength when it comes to understanding, that you automatically get a graph when you show it to the patient. (Chief physician, 2015-01-29)

Accordingly, the clinic liked the idea of using normal distribution to visualize the results and as a tool to help explain the results to the patient since it would both encompass the patient's results and the norm data. Another way to visualize the test results and the patient's ability to keep the car on the road (i.e. the primary task), suggested by the students, was to illustrate the car's trajectory on the road:

Student: One could for instance graphically draw exactly how the patient steered – that you get to see it yourself how the car related to the road. Or do you prefer to get a number of how many times the patient crossed a line?

Occupational therapist: No, but that's not a bad idea, it's pretty appealing to be able to show. (2015-01-29)

The clinic thought that this was more pedagogical than to present the patients with a number of how many times they had crossed the road markings. Another strength of this visualization was that it illustrated if the patient's driving got worse over time when the patient became tired, i.e. it visualized the patient's performance over time.

Yet another way to visualize the test results was to record the test to make it possible to go back and review it. This meant that what appeared on the screen during the test was recorded. One of the occupational therapists thought that it was good to be able to give feedback to the patients instantly and show where the patients missed stimuli, reeled a lot or displayed other deficiencies. This was especially helpful with patients who were not aware of their impairments or who did not understand when they drove poorly:

It would be optimal if you could show them directly that "This is how you did" or "Do you see here that..." or so. Especially for those who have trouble understanding, I mean, some people with brain injuries have a difficult time to take in information. But you still want to show them that there is a problem. They don't think there is any... 'There was this man a while ago, he was a truck driver even, he thought that "This was no problem at all, it went really well!"'. And I said "No, it didn't go really well..."'. (Occupational therapist, 2015-03-30)

Hence, using film was especially suitable for patients with brain injuries. According to the clinic, many of these patients tended to have great confidence in their abilities even though they performed poorly on the test and even though the occupational therapist tried to explain their deficiencies to them. The clinic hoped that these patients could be 'awoken' by watching their own test performances together with the health professionals.

Although the clinic liked many ideas on how to make the report intuitive, some ideas were rejected. For instance, during the contest, the competing team suggested that the results could be highlighted with different colors which would indicate how well the patient had performed. Green could indicate a normal or successful result whereas yellow and red could mean that the patient needed more assessment. One of the occupational therapists said that clarity was important but that this would be an oversimplification. She argued that even though a patient may get a 'green result', the health professional may assess that the patient is not fit to drive, hence, resulting in conflicting or confusing information for the patient.

In line with this, the clinic argued that all assessments had to be both 'quantitative' and 'qualitative', i.e. the test could not replace the qualitative assessment made by the health

professional. Instead, the test results were supposed to be complemented by the health professional's observations of the patients during the test:

Chief physician: In this kind of context, it's also about the one who observes the tests.

Occupational therapist: Yes, it is, of course.

Chief physician: Sometimes, the competence of the observer is more important than the test itself. (2015-02-25)

Even though the test *measurements* should not be affected by the health professional (as specified in the requirements, see Appendix B), the *assessment* of patients' fitness to drive were to be made by the health professional. That is, the decision if the patients were to keep their driver's licenses or not could not be made by the test and the report only.

4.8.4. Summary of designing the test results

Above, many examples of possible, impossible and uncertain designs of the test results have been given. The main points are summarized in Box 4.8.

Box 4.8. Summary of designing the test results

- When designing the test results, certain measures of the patients' cognitive abilities had to be included. Most of these measures were similar to those in the old driving simulator.
- Norm data were needed to make the results interpretable. Without norm data it was uncertain what was considered a normal or deviant performance. This uncertainty had to be resolved by conducting empirical research to establish norm data. It was also suggested that the new and the old test could be compared to define normal performances.
- The report had to be pedagogically illustrated to help the health professionals explain and the patients understand and accept the test results. Hence, it was considered inappropriate to only include numbers in the report since verbal explanations of these were hard for many patients to understand.
- It was possible to visualize the results as this enabled the patients to see their own performances and make it easier for them to understand if they were fit to drive or not. The visualizations also enabled the health professionals to provide instant feedback to the patient in other ways than verbal explanations only.
- However, it was not possible to make the visualizations too simplistic, e.g. by using different colors for the results, since the health professional may deem the patients unfit to drive even though they may get a 'green light' on the test. The decision if the patients were to keep their driver's licenses or not had to be made by the health professional, not by the test and the report only.

4.9. Epilogue

After the students' prototype had been developed and presented, the participants decided to conduct a pilot study in primary healthcare to validate the test before it could be taken into medical use. All of the participants were happy with the outcome of the project. For instance, the clinic argued that they thought that the students had designed a test that was consistent with what they had aimed for:

You have come close to the image I had in my mind of how it should be. (Chief physician, 2015-05-25)

Even though the new test resembled the old driving simulator in many ways, it attracted some publicity as a 'unique study' in a news item on national television. At the time of writing, the project is still ongoing with the intent to implement the evaluated test in healthcare organizations.

This chapter has described the driving simulator case. The empirical descriptions have provided the reader with an overview of the case and thereafter focused on possible, impossible and uncertain designs. In the next chapter, the possible, impossible and uncertain designs are analyzed and discussed in light of agential realism and also previous research about design and innovation.

5. Analysis and discussion

In this chapter, the empirical material is analyzed and discussed in light of theory in order to answer the research question. The chapter is divided into three parts. Part I focuses on the tests as boundary-making apparatuses. In Part II, the impossible, possible and uncertain designs are analyzed and discussed. In Part III, the previous analyses are discussed in light of prior research about IT design and innovation.

5.1. Introduction

In the previous chapter, the driving simulator case was presented. In this chapter, the case is analyzed and discussed using agential realism as a theoretical lens to understand why it was difficult to design innovative IT. Accordingly, this chapter presents the results from the theory-driven analysis. As mentioned in section 3.4.2. and 3.6.4., the agential realist analysis focuses on how boundaries are enacted in the case, what material-discursive practices enact them, and how those specific enactments are consequential. This means that the material configurations of the IT artifacts are examined. The agential realist analysis also focuses on *breakdowns*, i.e. instances when things do not work, such as the impossible and uncertain designs. Genealogical analysis, in the form of historical retrospectives, is also used to reveal the taken-for-granted and understand how boundaries are enacted.

One of Barad's (2007) main points in agential realism is that of entanglement. To present an analysis about entanglements in a way that is easy for the reader to follow poses a challenge. Since boundaries are part of enacting each other and become together, the text's sequential structure is of course imposed on the entanglements and calls for some repetition. Hence, the reader is asked to be patient with this. To avoid an unstructured account of the analysis, the chapter first describes and discusses important boundaries and gradually build up to a more complete picture of the apparatuses, boundaries and entanglements.

Furthermore, several concrete examples from the empirical case are used in the analysis to avoid a much too abstract or over-theoretical account. One aim of this is to make the rather abstract theory of agential realism more understandable. Another reason to be highly attentive to details is because they make a difference, according to Barad (2007). Hence, the reader is also asked to be patient with the details as they are needed to illustrate the conclusions. However, to counteract the risk of getting lost in details, the main points are summarized and highlighted in boxes throughout the chapter. The main arguments of the analysis and discussion are also briefly summarized in the introduction of each part of the chapter to give the reader an overview of the line of reasoning presented in the chapter. Hopefully, this will function as a backdrop that enables the reader to more easily follow the examples and details provided in the chapter while still having an idea of the bigger picture.

The chapter is structured as follows: Part I of the analysis focuses on the tests as boundary-making apparatuses and aims to investigate what boundaries the tests help enact. In Part II, it is analyzed why the designs were considered impossible, possible and uncertain. In Part

III, the analyses from Part I and II are discussed in light of prior research about design and innovation. This part focuses on the difficulties of designing innovative IT.

Part I – The tests as boundary-making apparatuses

Part I of the analysis focuses on the tests as boundary-making apparatuses and aims to investigate what boundaries the tests help enact. Four boundaries (e.g. subjects and meanings) are identified and presented including 1) the (un)fit driver, 2) the able patient, 3) the able health professional and 4) cognitive (dis)abilities. It is also discussed how these subjects and meanings are entangled and help produce each other. Highlighted here is the role of the design, i.e. the material configurations, in producing the different boundaries. As Barad (2007) points out, apparatuses are material configurations and boundary-making practices in which matter and meaning become locally determinate within phenomena. Several examples are given to illustrate how boundaries are defined and enacted by the material setup of the design and, thus, how materiality and meaning are inseparable (Barad, 2007). Accordingly, the takeaway message of Part I is that the tests help enact certain boundaries – subjects and meanings.

5.2. The enactment of boundaries

In the following sections it is suggested that the tests help, or should help, enact certain subjects and meanings. These are 1) the (un)fit driver, 2) the able patient, 3) the able health professional and 4) cognitive (dis)abilities. The subjects and meanings that the tests help produce are described one at a time below. However, these are entangled and become together, which is discussed by the end of this section. I here emphasize that the tests *help* produce these boundaries in the sense that they are not the only apparatuses to do this. As Barad (2007) points out, apparatuses are always open-ended and, thus, the old driving simulator and the new test do not perform these boundaries in isolation. Several other material-discursive practices are part of these enactments (as discussed in 5.4.7.). However, for analytical clarity, the following sections focus specifically on the old driving simulator and the new test.

5.2.1. Enacting the (un)fit driver

As was described in the initial part of the empirical chapter, the old driving simulator is a device used by the clinic to discriminate between fit and unfit drivers, i.e. to assess which patients are considered able to drive safely after brain injury and those who are not. In this sense, the old driving simulator is an apparatus that health professionals need to distinguish between fit and unfit drivers. Who is an unfit driver or not cannot be distinguished simply by talking to the patient, as pointed out by the clinic:

You need a tool to assess this, it's not possible to assess just by face-to-face interaction. (Occupational therapist, 2014-10-13)

Accordingly, the old driving simulator is an apparatus for differentiating and drawing a boundary between fit and unfit drivers, thus, creating different subjects – the fit driver and the unfit driver (hereafter referred to as *the (un)fit driver*). The new test also had to be able to make this distinction (elaborated below).

Important to point out here is that patients are not inherently fit or unfit drivers but *become* fit or unfit in the clinic's assessment by use of the tests. One way to exemplify this is the VTI researchers' argument that it is very difficult to foretell who will drive safely or not even if they have the right preconditions for driving. They argued that even those who are considered unfit drivers may drive for a long time without being involved in an accident. Accordingly, this binary division of fit and unfit driver is, from an agential realist perspective, not pre-existing but is coming into being through specific configurations, as shown in this chapter.

Specific designs (configurations) of the tests were needed for the subject (un)fit driver to be enacted. The clinic argued that a test that resembled car driving helped patients understand and accept the test and the results. That is, it was advantageous if patients experienced that they had been assessed in terms of their driving abilities since this would help them understand and accept their cognitive impairments and that they were unfit to drive – they would identify as unfit drivers. Similarly, patients who did not have cognitive impairments would identify as fit drivers. The clinic found it problematic if patients did not think that the tests assessed car driving, e.g. the paper-and-pencil tests, as this did not convince the patients that their driving abilities had been assessed – they would not identify as unfit drivers. Hence, *a design that made patients understand and accept the test and the results helped enact the subject (un)fit driver*. It was due to this that the clinic emphasized ecological validity to such a great extent. An ecologically valid test that resembled car driving helped patients understand and accept the test, the results and their (un)fitness to drive. In this sense, designs with ecological validity was an essential part of enacting the (un)fit driver.

However, the participants had a hard time coming to a joint understanding of what was meant by ecological validity and how to design for it, and thus help patients understand and accept the test. How should the test resemble car driving and to what extent? As the participants engaged with and discussed various technological setups (material configurations) during the workshops, specific setups proved to be important to make the test resemble car driving and, thus, make patients understand the test's relevance for assessing fitness to drive. This included that the patients were to act and react in a way similar to driving. The clinic argued that the paper-and-pencil tests were not enough to make patients understand and accept that their driving abilities had been assessed, i.e. this design would not enact the (un)fit driver. Furthermore, a key feature to achieve ecological validity was that the test had a steering wheel. The steering wheel was important since it made the test resemble car driving and that the patients got to show 'what they can do' in terms of driving. An essential part of being a driver is steering, which made the steering wheel a suitable design for enacting the subject 'driver'. Accordingly, the material configuration of the

steering wheel was important to achieve understanding and acceptance – producing the subject (un)fit driver.

Other designs that were part of enacting the (un)fit driver were the design of the driving experience and traffic environment. Here, the clinic required a specific design (configuration) to make the patients feel that the test resembled car driving, including a realistic traffic environment with a road and a feeling of forward movement. The design of the practice parts was also important to make patients understand and accept the test, which helped in enacting the (un)fit driver. Furthermore, the design of the test report also played an important part in enacting the (un)fit driver. Even though explanations and dialogue with the patients were important, explaining the test results verbally to the patients was not always enough to make them understand that they had impaired abilities, which made them unfit to drive. Therefore, the clinic preferred if the report was pedagogical and intuitive with visualizations of the results. They argued that this could help patients understand how they performed on the test, i.e. if they were fit to drive or not. To conclude, specific designs (material configurations) helped produce the subject (un)fit driver.

5.2.2. Enacting the able patient

The (un)fit driver was not the only subject that the test had to help enact, it also had to produce the able patient. Of course, patients become in a multitude of material-discursive practices and what is suggested in this discussion is only a fraction of the apparatuses that enact this subject (some of which are mentioned in 5.4.7.). Still, certain designs were important in the enactment of the able patient. For instance, it was important that the people who took the test felt like able patients, i.e. that they felt competent when taking the test, that they had the chance to actually show what they were capable of and that they could perform at their best. Hence, the test had to be designed so that everyone could become able patients, despite e.g. potential (physical) impairments. One way in which the able patient was produced was through practice before taking the test. By practicing on the tasks and trying out the steering wheel, the patients felt more competent, e.g. that they were capable of maneuvering the steering wheel and that they understood the tasks. This gave them the opportunity to perform at their best, which contributed to that patients would accept the results, according to the clinic. Hence, the tests had to have a specific design to make the patient able, i.e. to produce able patients.

5.2.3. Enacting the able health professional

The able health professional also comes into being in a multitude of material-discursive practices. What is highlighted in this section is how the design of the test helped enact this subject. One of the main tasks of the health professional was to assess if patients had the required cognitive abilities needed for driving, and preferably in a way that made the patients feel fairly treated. As pointed out above, this assessment cannot be done without a specific instrument that helps measure these abilities. Hence, health professionals needed to have and be able to use measurement instruments to become *able* health professionals.

In this sense, the able health professional came into being together with the test. Their tasks were both to discriminate between those who were unfit and fit drivers, make them understand and accept the test and the results and to help patients feel able while taking the test. In this sense, being an able health professional means to help produce the subjects (un)fit driver and able patient (and also cognitive (dis)abilities, see below). Or put differently, the subject able health professional become together with the (un)fit driver and able patient. If the health professionals cannot distinguish between those who are (un)fit to drive or make the patients feel able, then they would not be able to perform their job, making them *unable* health professionals.

The design of the test that helped enact the able health professional included measurements of the patients' cognitive (dis)abilities (described in the next section) and the configuration of a pedagogical report to help the health professionals explain the test results to the patients and make them understand and accept them. In this sense, the health professional was an important part of enacting the (un)fit driver. The design also had to enable the health professional to help and instruct the patients. The latter was accomplished by a screen which both the patient and the health professional could see, so that they could instruct the patients while they took the test or assess if the patients needed more practice to maneuver the wheel or understand the task. To conclude, specific arrangements of the design enacted the able health professional.

5.2.4. Enacting cognitive (dis)abilities

Above, it was argued that patients are not inherently fit or unfit to drive, but *become* (un)fit drivers in specific configurations. Likewise, the cognitive (dis)abilities discussed in this thesis are not considered inherent, pre-existing traits that people intrinsically 'have', but become distinct in and through specific material-discursive practices. That is, they become determinate and meaningful in specific configurations, or as put by Barad:

[C]oncepts are meaningful, that is, semantically determinate, not in the abstract but by virtue of their embodiment in the physical arrangement of the apparatus. (Barad, 2007, p. 117)

In the same way, the cognitive (dis)abilities are meaningful, that is, semantically determinate, not in the abstract but by virtue of their embodiment in the physical arrangement of the apparatus. Put differently, the cognitive (dis)abilities cannot become determinate without the apparatus – a 'tool' is needed to know them, as also argued by the clinic. The following sections investigate how the cognitive (dis)abilities become distinct through the specific designs of the old driving simulator and the new test.

Attention and reaction

What attention and reaction meant became determinate by the apparatuses used in the case. One of the tasks that the patients were to perform in the old driving simulator was to press the right or left button on the steering wheel as quickly as possible when the arrows pointed to the right or left on the side screens. From the report, the health professionals could then say whether the patients had normal or deviant attention and reaction. The configuration

of the old driving simulator which enacted attention and reaction, included the two screens (on the sides of the center screen), stimuli on these screens in the form of triangles with arrows, buttons on the steering wheel, numbers in the report (e.g. measurements of reaction time, correct responses, missed stimuli) and comparative values. The new test had a similar configuration as the old driving simulator. Hence, these specific arrangements produced the abilities attention and reaction (or the lack thereof).

That the configuration enacted these (dis)abilities may not be apparent when the apparatus works as intended, but it becomes noticeable when it breaks down in some way. For instance, the buttons on the old driving simulator's steering wheel were 'glitchy' and stiff which could affect the patients' results. The stiff buttons could make the patients' responses appear slower than they were or that the simulator did not register a response at all even though the patients had pushed the correct button. Accordingly, the patients could be considered 'inattentive' or 'slow' due to the buttons' stiffness. To have attention and quick reactions or not was thus a result of the specific configuration of the test. In this instance, the patients, their hands and the buttons became especially salient. The strength of the patients' hands and the stiffness of the buttons were part of producing attention or inattention, i.e. enacting these meanings. Similarly, if the patients had a hard time to find or reach the buttons, this would affect their response times and results – enacting them as slow or inattentive. In this way, the physical arrangement of the apparatus (the design of the test) enacted attention and reaction in a specific way. (Dis)ability in terms of attention and reaction were thus accomplished by this specific configuration – the patients *were enacted* as attentive or inattentive and fast or slow by the specific configuration.

Processing ability

In the old driving simulator, processing ability was enacted by making the patients distinguish between if the arrows pointed to the left or to the right and then push the corresponding button. The numbers in the report, e.g. incorrect responses, showed if the patients could distinguish between arrows that pointed left or right and react accordingly. If they had a lot of incorrect responses, this indicated that they had an impaired ability to process information. Missed stimuli and slow reaction times were also indications of potential impaired processing ability, i.e. that the patients did not manage to process information quickly enough. That is, processing ability was enacted in a design that included buttons on the steering wheel, two screens, stimuli with arrows pointing left and right, numbers in the report, and comparative values. The new test had a somewhat similar design, discussed in more detail in 5.5.1.

Cognitive load and simultaneous capacity

The enactment of cognitive load differed between the old driving simulator and the new test. In the old driving simulator, cognitive load was enacted by a specific configuration including a road and a feeling of forward movement on the screen, simulated wind with individualized levels of difficulty, a steering wheel, the duration of the test, a number in the report and a comparative value. In the new test, cognitive load was enacted through a

configuration including a moderately curvy road and a feeling of forward movement on the screen, a steering wheel, the duration of the test and a test result that visualized how much the patient reeled on the road. Hence, two different designs were used to enact cognitive load.

Simultaneous capacity was produced by making the patient perform the primary and the secondary task at the same time. In the old driving simulator, patients were both to keep the car on the road while compensating for the simulated wind and distinguish between whether the arrows pointed left or right and then push the corresponding button. Accordingly, simultaneous capacity was here defined by this specific design which included the configuration of cognitive load (the primary task) and the configurations of the attention, reaction and processing ability (the secondary tasks in the old driving simulator), described above. In the new test, simultaneous capacity was enacted by a similar configuration, i.e. a combination of the primary and secondary tasks.

The descriptions above illustrate how subjects and meanings – boundaries – come into being through specific physical arrangements of the design and, thus, always are material (Barad, 2007). What it means to be an (un)fit driver, able patient or able health professional and the meanings of cognitive (dis)abilities are defined in specific material configurations of the design. This also illustrates how these boundaries are both matter and meaning and cannot be separated (Barad, 2007).

5.2.5. Entanglements of subjects and meanings

As indicated above, the described subjects and meanings were not enacted in isolation but became together – they were entangled. That is, they were part of enacting each other. Barad (2007) describes phenomena as existing of entanglements or intra-actions, which include both apparatus and boundaries. This means that the subjects and meanings are becoming in intra-action with each other and the test (the apparatus), and thus help constitute one another. For instance, for a person to become a patient, she has to be under medical investigation by a health professional. Vice versa, the health professional becomes a health professional by assessing patients. In this sense, they are producing or co-constituting each other.

Furthermore, the (un)fit driver and the able patient were entangled. To enact the (un)fit driver, the patients first had to become *able* patients. This was achieved through the specific configurations exemplified above. If the test enacted *unable* patients who were not able to take the test as intended, this would make it harder for patients to understand and accept the test, or maybe even impossible for them to take the test at all. If the patients did not feel that they could take the test due to e.g. physical impairments, they would not feel that they had a chance to show their ability to drive and, hence, this would diminish the likelihood that they would accept the test results. Consequently, they would not identify as (un)fit drivers. In this sense, being an able patient was also part of enacting the (un)fit driver and, thus, these subjects were entangled. Similarly, the enactments of the cognitive

(dis)abilities were part of enacting the (un)fit driver, i.e. if the test indicated disabilities in attention or reaction, this would contribute to the enactment of the unfit driver.

Moreover, the able health professionals were entangled with both the (un)fit driver and the able patient since, by performing their job, they were a part of enacting these subjects and meanings. For instance, the clinic argued that the assessment of cognitive (dis)abilities and (un)fitness to drive was a matter of both quantitative measures, i.e. the test results, and qualitative assessments, i.e. the health professional's observations and interpretation. However, they emphasized the role of the health professional and argued that the test could not replace the health professionals. That is, the test should help in the enactment of the (un)fit driver, but the health professional had the last word in deciding who was (un)fit to drive. Put differently, the (un)fit driver could not be enacted *without* the health professional. In this sense, the able health professional is made distinct in entanglement with the enactments of the (un)fit driver and able patient, and being an able health professional meant to produce these subjects. The take-home message here is that these boundaries (subjects and meanings) are entangled, i.e. become together and are part of producing each other.

5.3. Summary of Part I

Part I has illustrated and discussed the boundaries that the tests are part of producing. Four subjects and meanings were identified; 1) the (un)fit driver, 2) the able patient, 3) the able health professional and 4) cognitive (dis)abilities. It was also noted that these were entangled and become together. The section also highlighted the role of the design (the material configurations) in enacting these subjects and meanings. That is, specific physical arrangements of the design produced the different boundaries.

Summary: The test design, i.e. the material configuration of the test, enacts different boundaries, including the (un)fit driver, the able patient, the able health professional and cognitive (dis)abilities. These boundaries are entangled.

Part II – Impossibilities, possibilities and uncertainties in the designs

Now that an overview has been given of what and how boundaries were enacted by the tests, Part II of the discussion focuses on why the designs were considered impossible, possible and uncertain. Here, the main argument is that designs were impossible if they did not help enact subjects and meanings as desired or similar to what had been enacted before since this would have redefined the subjects and meanings in undesirable ways, i.e. enacted these boundaries differently. To enact a boundary as desired means to enact it in line with prevailing material-discursive practices, whereas undesired boundaries are *not* in line with prevailing practices. That is, 'desired' means that a certain meaning was preferred, wanted or required. This is elaborated in section 5.4.7. Designs were possible if they aligned with existing material-discursive practices whereas designs were uncertain if it was not clear what boundaries they would help produce. The takeaway message of Part II is that impossible,

possible and uncertain designs are enabled and constrained by several material-discursive practices. The following sections are structured as follows: First, impossible designs are discussed, followed by an analysis of possible designs. Finally, uncertain designs are considered.

5.4. Impossible designs

In the participants' discussions, many suggested designs were considered impossible. Technological setups that did not resemble the old driving simulator were especially problematic. Hence, the designs that were considered more 'innovative' or 'novel' were rejected, such as the VR headset and the tablet. The following sections exemplify and discuss why some designs were considered impossible. To analyze this using agential realism as a theoretical lens, we must go back to Barad's understanding of apparatuses. She states that "*the nature of the observed phenomenon changes with corresponding changes in the apparatus*" (2007, p. 106, emphasis in the original). In this case, the apparatus is the test and, thus, if the test is changed (by designing it differently), then there will be changes in the phenomena, i.e. other boundaries will be produced. That is, if the design of the test changes, it will produce different subjects and meanings. On the contrary, if the design of the test does not change, it is more likely to produce the same subjects and meanings. The main point presented here is that designs that did not enact the subjects and meanings as desired were considered impossible. That is, these designs would have redefined these boundaries, i.e. changed the meaning of the (un)fit driver, able patient, able health professional and cognitive (dis)abilities.

5.4.1. The design did not enact the (un)fit driver as desired

As mentioned above, it was important that the test had ecological validity and enacted the (un)fit driver. Before choosing the laptop solution, the participants tried different technological solutions with different instances of 'steering wheel' – the tablet as a wheel, the VR headset and Wii wheel and the laptop gaming racing wheel. The participants' discussions about these proved that not any steering wheel would do to help enact the (un)fit driver – a specific design (physical arrangement) was needed to do this.

For instance, there was a delicate balance between how realistic or unrealistic the steering wheel had to be. Steering wheels that were handheld and thus 'floated' in the air or could be turned in any direction, like the tablet and Wii wheel, were considered unrealistic. Furthermore, it was a deviation from reality if the steering wheel also was a windshield, like the tablet, or if the patients could not see the wheel, as in the VR headset. Similarly, if the test was too game-like it would not be convincing. These designs (or physical arrangements) were considered impossible and were excluded since they would not create a test with ecological validity – they would not resemble a realistic car driving situation and, thus, would not help enact the subject (un)fit driver. Or put differently, these designs would not make patients identify as (un)fit drivers – the test would not convince them that the test assessed their abilities to drive and, hence, they would not understand and accept the results

– the subject (un)fit driver would not be enacted. Accordingly, one reason why these designs were considered impossible was that they did not help produce the (un)fit driver as desired.

Another way to put it is that the impossible designs would have enacted *other* boundaries than that of the old driving simulator. That is, more patients could have identified as fit drivers in the new test (even if they were not when taking the old test) since they might not be convinced that they had been assessed in terms of car driving. Thus, the boundary or demarcation between fit and unfit would have been drawn somewhat differently, resulting in a difference in who identified as (un)fit driver or not. In this sense, the test and its specific design are important parts in producing the world – it makes differences in who becomes what.

5.4.2. The design did not enact the able patient as desired

The rejected designs were not only considered impossible due to that they did not enact the (un)fit driver. They were also considered impossible since patients would have difficulties using the technology and performing the test tasks, i.e. they would not become able patients. As the patients were not supposed to fail the test due to problems maneuvering the device, many of the car gear discussed by the participants were excluded. This was partly due to the entanglement of the subjects able patient and (un)fit driver. If the test's sole purpose would have been to enact the (un)fit driver, the test could have been more realistic, e.g. it could have included car-like features to make the test more convincing. However, as the test also had to enact the able patient, it was limited how realistic the test could be.

For instance, gas and brake pedals and gear stick could have contributed to the test's ecological validity as they would have made the test resemble car driving more. However, pedals were excluded since they would prevent patients in wheelchairs from taking the test – making them unable patients. That is, to include pedals would mean that it would not be possible to assess their cognitive (dis)abilities due to their physical disability. Hence, this design would make it impossible for these patients to maneuver the test, making them unable patients.

Another hindrance to maneuver the device successfully was if the patient could not see the buttons properly. In the VR headset, patients could not see the steering wheel, making it difficult both to understand the test's similarity to car driving and to press the correct button (e.g. left and right) as the buttons were not visible. Accordingly, this design was considered impossible since it did not help enact the able patient but rather *unable* patients.

An important aspect in terms of maneuverability was that patients should be able to only use one hand when taking the test. Because of this, gear stick was excluded since the patients would have had to let go of the steering wheel to change gear, which would have affected how well they kept the car on the road and if they missed stimuli. Similarly, the tablet car racing game was considered impossible since the tablet was not fixed and, thus, was difficult to maneuver. It would especially be difficult for patients who could only use one hand or had weakened hand strength since they would have to both hold the tablet and react to

stimuli using only one hand. To become an able patient, patients had to be able to steer and maneuver the device properly. Accordingly, the physical arrangements of the gear stick and tablet did not enact the able patient as desired.

Not even the laptop steering wheel enacted the able patient as desired even though it resembled the old driving simulator to a great extent. As mentioned in the empirical chapter, the laptop steering wheel had a lot of asymmetrically placed buttons in the middle on both the front and back of the wheel, which were hard to reach when steering (see Figure 4.9. in Chapter 4). Due to the placement of the buttons, it was only possible to push the buttons with the right hand in the students' prototype. Accordingly, patients who could only use their left hand would not be able to take the test, which would make them unable patients. Similarly, the toughness of the buttons on the laptop steering wheel also made it difficult for patients with weak hands to react as quickly as others, making it harder for them to feel competent when taking the test. This would also affect their response times which enacted them as attentive or not. In contrast, the wheel of the old driving simulator was symmetrical, making it possible for patients to easily steer and push the buttons with both hands, or the right or left hand only (see Figure 4.8. in Chapter 4). Thus, the material configuration of the old driving simulator's steering wheel enacted the able patient as desired, whereas the configuration of the laptop steering wheel did not.

This example illustrates how the *details* of the design made a profound difference in what subjects were enacted and what they meant. The details of the design (the specificity of the material configuration), that is, how the test was physically arranged in terms of the buttons, made a difference for what subjects and meanings were enacted. In this sense, the positions and toughness of the buttons were part of the configuration determining the boundary between able and unable patient (and to some extent also the (un)fit driver and cognitive (dis)abilities). In the configuration of the laptop steering wheel, patients who could only use their left hand were enacted as unable patients, whereas they were not when using the steering wheel of the old driving simulator – the boundary was drawn differently depending on the physical arrangement (the design). Accordingly, the configuration of the laptop steering wheel did not enact able patients in the same way as in the old driving simulator, that is, what it meant to be an able patient would be somewhat redefined. The clinic was not interested in redefining the meaning of able patient and, hence, the new test had to have a design that enacted similar meanings as the old driving simulator, rendering the buttons on the laptop steering wheel an impossible design. Or put differently, the design of the buttons on the laptop steering wheel did not help enact the able patient as desired.

There were also other impossible designs that did not have to do with maneuverability of the test. For instance, traffic rules were excluded since patients who had not acquired their driver's licenses should be able to take the test. Patients should not fail the test due to lack of knowledge about traffic rules. It was their cognitive (dis)abilities that the test should assess. Hence, it was impossible to include traffic rules (even though this would have improved the ecological validity) as this would enact unable patients. The test had to help enact the able patient even if the patient did not have a driver's license.

Other designs that did not enact the able patient as desired were the VR headset and a too realistic driving experience in the laptop solution. These designs were considered impossible since they could cause motion sickness. If the patients became nauseous, this would make it harder for them to perform their best and feel competent while taking the test. Hence, if the test caused motion sickness, it would enact unable patients, i.e. these designs would not enact the subject able patient as desired even though they could have increased the ecological validity of the test.

The clinic also argued that older patients may become scared by technology. This was an issue since a lot of the patients at the clinic were of old age and potentially worried and confused due to dementia. In the same way as with people with physical impairments or motion sickness, these patients were also supposed to be able to take the test as intended. By using technology that would not scare the patients too much, it was easier for these patients to feel able. On the contrary, if patients were very scared and felt that they could not handle the technology, this would prevent them from performing their best during the test, making them unable patients. Examples of designs that were impossible in this regard were the VR headset, where patients would be encapsulated and possibly both scared and motion sick, and also designs with curvy roads and large screens, since this could make patients nauseous. These designs were considered impossible since they did not enact the able patient as desired.

To conclude, many designs were considered impossible since they did not enact the able patient as desired. To enact the able patient, a very specific design was required in which it was taken into account how different types of people could become able patients – not any technological setup would do to perform this subject as desired. This limited the number of designs that were possible which made it difficult to design something more innovative. If they were to redesign the test, they had to find a material configuration that both enacted the able driver *and* (un)fit driver as desired. That is, coming back to Barad's (2007) idea that changes in the apparatuses entails changes in the observed phenomenon (i.e. the boundaries), this means that changing the design will change the boundaries, in this case the subjects (un)fit driver and able patient. In the examples above, it has been illustrated that changing the design would enact different boundaries which would lead to unwanted changes in what it meant to be an able patient and (un)fit driver. Accordingly, one reason why the new test was similar to the old driving simulator was because a similar design would enact similar boundaries. More novel technological setups like the VR headset and the tablet did not enact the boundaries as desired and, consequently, these were considered impossible and were rejected.

5.4.3. The design did not enact the able health professional as desired

The test also had to help enact the able health professional. However, several designs were considered impossible since these did not produce this subject as desired. As stated above, one way in which the able health professional was coming into being was by enacting the able patient. For instance, this was done by helping the patients during the test. According

to the clinic, helping was important to make patients understand the test and the tasks. The importance of this became clear in the designs where this was inhibited. For instance, the clinic argued that having patients encapsulated by the VR headset would prevent the health professionals from seeing what the patients saw and, thus, inhibit their possibilities to communicate with, instruct and help the patients.

This example illustrates how the health professionals were needed to help the patients become *able* patients and by accomplishing this, the health professionals became *able* health professionals. The example also shows how certain physical arrangements (such as the VR headset) made it difficult or impossible for the health professionals to perform this task and, thus, the design did not help enact the able health professional. Instead it risked enact the *unable* health professional who could not help enact the able patient. Accordingly, the design of the test had to both produce the able health professional as well as the (un)fit driver and able patient. In this example, a screen that could be viewed by both the patients and the health professionals at the same time was preferred as this physical arrangement helped enact both the able health professional and able patients (and, thus, by extension, the (un)fit driver). Similarly, the health professional also became able by enacting the (un)fit driver, i.e. the health professionals had to be able to assess who is fit to drive or not. Hence, designs that did not enact the (un)fit driver as desired also inhibited the enactment of the able health professional (see impossible designs mentioned in section 5.4.1.).

Other impossible designs in terms of the enactment of the able health professional had to do with the report. For instance, to verbally inform the patients about how impaired cognitive abilities affect car driving was often not enough to make patients understand and accept the test. Hence, the clinic preferred a pedagogical report. However, there were also limitations to this. Even though the report should be pedagogical and intuitive, it could not be too simplified as this would be at the expense of the enactment of the able health professional. As mentioned in the empirical chapter, illustrating the results with different colors, e.g. green for a normal or successful result, yellow and red for patients who needed more assessment, was considered an oversimplification. This design was not approved by the clinic since they argued that there also had to be a qualitative assessment of the patients, e.g. through observations of the patients. That is, health professionals may deem patients as unfit to drive even though they got a ‘green light’ on the test. Hence, the test could not be designed so that the health professionals were made redundant (this is elaborated in section 5.4.7.). In summary, designs that did not help enact the able health professional as desired were considered impossible.

5.4.4. The design did not enact the cognitive (dis)abilities as desired

Some of the impossible designs discussed previously were also considered impossible, not only because they did not enact the subjects, but also because they did not enact the cognitive (dis)abilities as desired. As mentioned above and as the following examples show, the enactment of subjects and the cognitive (dis)abilities were entangled. For instance, enacting the able patient was a prerequisite for determining the cognitive (dis)abilities.

Without an able patient, it would not be possible to know if the test measured the patients' cognitive (dis)abilities or something else. For example, designs which could cause motion sickness were excluded since these configurations would make it ambiguous if the patients' results were due to cognitive disabilities or to nausea. Similarly, designs that were hard to maneuver would also make it ambiguous whether the results were due to the patients' cognitive disabilities or their inability to operate the test. This meant that designs that were hard to maneuver with one hand were excluded, such as the tablet, gear stick, buttons that were hard to reach, see and push. Similarly, the steering wheel could not be too sensitive or too unresponsive, not only because this would be unrealistic, but also because this would make it difficult to determine if patients' reeled on the road was due to the patients' cognitive disabilities or an effect of the steering wheel's sensitivity, i.e. that it was just difficult to maneuver the wheel. Accordingly, the steering wheel sensitivity had to have a specific configuration to help determine the cognitive (dis)abilities in an unambiguous way, and was therefore also a part of enacting the cognitive (dis)abilities.

Furthermore, having a lot of gear would make the test more complex and would increase the difficulty of interpreting the results – what was really measured? Hence, the requirement of ecological validity and the test's resemblance of a real car driving experience were constrained by the test's ability to measure and determine the cognitive (dis)abilities as unambiguously as possible. For instance, traffic rules were excluded since the test was supposed to be able to measure patients' cognitive (dis)abilities even though they did not have knowledge about traffic rules. That is, including traffic rules would have made the results unclear – did the patient fail due to impaired cognitive abilities or due to lack of knowledge about traffic rules?

In summary, it was important that the cognitive (dis)abilities were enacted unambiguously since these also were a part of enacting the (un)fit driver and able health professional. That is, the health professional had to be able to distinguish between fit and unfit drivers, which partly was done by determining the patients' cognitive (dis)abilities. If the test could not perform these (dis)abilities, it would not help the health professionals to distinguish between fit and unfit drivers and, thus, would not help enact neither the able health professional nor the (un)fit driver. Accordingly, many of the suggested designs were impossible for several reasons. That is, enacting the able patient was important not only for making the patients feel competent, but also to ensure that the test actually measured the cognitive (dis)abilities. To achieve this, the test had to be easy to maneuver and not too complex. That is, certain designs were considered impossible since they were hard to maneuver and too complex and, consequently, would not enact the cognitive (dis)abilities as desired.

Enacting cognitive load

In the new test, many of the cognitive (dis)abilities were enacted through similar configurations as in the old driving simulator (as discussed in section 5.5.1.). However, the configuration of cognitive load was somewhat redesigned (elaborated in section 5.5.2.). The partici-

pants discussed how the new test should be designed to make sure that the patients experienced a cognitive load. The main idea was that the primary task should take some effort and concentration to perform successfully. Accordingly, the cognitive load could have been created in numerous ways as long as the primary task took some effort to perform.

Curves were considered a possible design as this contributed to the ecological validity *and* created a cognitive load, but the specificity of this design was restricted as well. The road could not be too curvy since this could cause motion sickness, and thus, enact the unable patient. Neither could the road be too straight as this would make it too easy, meaning that the patients would not experience a cognitive load. Accordingly, there had to be a specific level of curviness in the road – a specific configuration – for the test to enact a cognitive load. Hence, this is another example that illustrates how the details of the design make a profound difference for what is enacted.

To conclude, some designs were considered impossible since they either did not help enact cognitive load as desired, did not enact the able patient or did not contribute to ecological validity and, thus, did not enact the (un)fit driver. Hence, even though other and new designs to create a cognitive load were theoretically possible (i.e. that the patients had to put in some effort and concentrate), this proved to be difficult since the test design also had to enact the able patient and (un)fit driver.

Enacting one-sided brain injury

As mentioned in the empirical chapter, it was important that the test could identify one-sided brain injuries, i.e. distinguish between the hemispheres. Several designs were considered impossible since they did not manage to do this. This included the tablet and the laptop screen since these were too narrow, meaning that stimuli would be presented in the central field of view. This would make it impossible to discriminate between if stimuli were processed by the left or right hemisphere. In other words, this design would not enact one-sided brain injuries as desired and were therefore considered impossible.

Another impossible design was to test the patients' peripheral vision manually by holding up two fingers on the sides of the patients and slowly moving the fingers from the periphery to the central visual field until the patients noticed them. This was considered impossible since the patients would not be under a cognitive load during this type of test. That is, the patients may detect the fingers without a problem but had they been under a cognitive load, the brain might not have processed it properly. Accordingly, it was impossible to detect one-sided brain injuries by only holding up two fingers in the periphery without the patients being under a cognitive load. Or put differently, this physical arrangement would not enact one-sided brain injuries as desired.

To enact the one-sided brain injury, a specific design (configuration) was required. This included that stimuli were presented in the peripheral visual field and that the patients were under a cognitive load, i.e. to perform both a primary and a secondary task. The position of stimuli were essential for enacting the brain as divided into two hemispheres – they had to be in the periphery and not in the central visual field to be able to detect side differences

in patients' cognitive (dis)abilities. In the old driving simulator, two screens were used to enable a wide angle. In the new test, this configuration had to be specified further since it was uncertain exactly what angles were needed to make sure that stimuli did not occur in the central field of view (discussed further in 5.6.).

The main point here is how the details of the design makes a difference for what is enacted or not – what boundaries are produced. With a narrow angle, the brain is produced as 'one entity' whereas a broader angle enacts the brain as divided into two hemispheres. Accordingly, to enact one-sided brain injuries, the details of the design becomes crucial and, hence, more 'novel' or innovative technologies such as the tablet was considered impossible since they did not enact this boundary as desired.

5.4.5. The design did not enact all these entangled boundaries

As the previous sections indicate, many designs were considered impossible because they did not produce *all* of the boundaries (i.e. the identified subjects and meanings) as desired. Some designs enacted some subjects or meanings but not others and, because of that, the design was considered impossible. For instance, the VR headset helped enact the (un)fit driver since it resembled car driving and, thus, was convincing. It also helped in the desired enactment of one-sided brain injuries since the screen had a wide angle. However, this design did not enact the able patient since patients could become motion sick or intimidated by the technology. Neither did it enact the able health professional since the design did not allow health professionals to follow the test and help the patients during the test. Hence, since the test could not enact *all* of the desired meanings, it was considered impossible.

Furthermore, as also indicated in the previous sections, details matter for what subjects and meanings are enacted. The illustrations above show how every boundary required its very own specific configuration. Since the same test had to enact many different boundaries, all of these details had to be taken into account in a joint manner without failing to enact all the boundaries. To illustrate; if the screen was too wide it could cause motion sickness and would not produce the able patient, but if it was too narrow it would not produce one-sided brain injuries. Similarly, if the traffic environment was too unrealistic it would not convince patients that their fitness to drive was measured, inhibiting the enactment of the (un)fit driver, but if the environment was too realistic this could cause motion sickness (enact the unable patient) and also make the test too complex which would make the cognitive (dis)abilities ambiguous. Likewise, if the road was too curvy it could cause motion sickness, but if it was too straight it would not create a cognitive load. Hence, the details of the design were essential and that the test enacted several entangled boundaries through these details is one explanation of why it is difficult to change a design. The change may be possible to some extent (as the examples above illustrate), but it may change other boundaries, subjects and meanings in undesirable ways. Hence, a barrier to designing innovative IT is that changes in the design often comes with changes in enacted boundaries, i.e. shifts in subjects, objects, matter and meaning (following Barad's, 2007, line of thought).

5.4.6. Summary of why some designs were impossible

Before moving on, it is useful to summarize the main points made so far in Part II. The above examples illustrated how many designs were impossible since they did not enact the subjects and meanings (boundaries) as desired. The impossible designs would have redefined the meaning of the (un)fit driver, the able patient, the able health professional and the cognitive (dis)abilities, i.e. the boundaries would have been enacted differently by these designs. The examples have also illustrated the importance of details in the designs, i.e. the specificity of the physical arrangement, and how these made a difference for what boundaries were enacted or not. That is, every boundary was enacted by a specific design where the details mattered. This also shows how the specific designs are important parts of producing the world in a certain way and that the test and its design makes a difference in who becomes what, i.e. who is considered fit or unfit and able, unable or disabled.

Furthermore, the boundaries were entangled and part of producing each other which means that the test (and the details of the design) had to enact all of these boundaries as desired, otherwise the design was considered impossible. This limited what was possible to design. These examples point to some clues about why it is difficult to design innovative IT. In the empirical case, it was difficult (or impossible) to change the design of the test (the IT artifact) and use more innovative or novel technological solutions since this would change the enacted boundaries in undesirable ways.

Summary: Many designs were considered impossible since they did not help enact the boundaries (subjects and meanings) as desired. Instead, the impossible designs would have redefined these boundaries in undesirable ways. Details in the design matter for what is enacted or not and the design had to enact several entangled boundaries as desired. This limited what was possible to design and inhibited a design that differed from the old driving simulator.

5.4.7. Defining what is desirable

By now, the attentive reader probably wonders why some enactments are considered desirable and others not. This question requires us to take a broader perspective on the case. Up until now, we have focused on the tests as apparatuses in a rather small context, but we may also change our perspective to consider how the boundaries are coming into being in a multitude of material-discursive practices. Here, a short recapitulation of some of concepts from agential realism is in place to facilitate the following discussion.

As mentioned in Chapter 2, apparatuses and material-discursive practices are used interchangeably in this thesis. Also, matter and meaning are seen as inseparable which is denoted in the term ‘material-discursive’. Hence, when raising issues of the design’s material configuration this also has implications for the *meaning* of it and vice versa (as the many examples above have illustrated). Put differently, Barad (2007) argues that meaning is made possible through discursive practices where these practices are defined as apparatuses or

“specific material (re)configurings of the world through which the determination of boundaries, properties, and meanings is differentially enacted” (Barad, 2007, p. 148, emphasis in the original). Hence, discursive practices are material configurations that enact certain boundaries (again, as was illustrated in the examples above). Furthermore, discourse is defined by Barad (2007, p. 146) as “that which constrains and enables what can be said”. However, as discourse is not reduced to language or words, this includes materiality (i.e. matter and meaning are inseparable). In this sense, discourses (or material-discursive practices) constrain and enable both what can be said but also what can come into being – both in terms of materiality and meaning – and, thus, what can be designed.

The take-home message is that, according to my interpretation of Barad, these concepts (such as material-discursive practices, material practices, discursive practices, apparatuses, material configurations, physical arrangements, entanglements and intra-actions) all denote *the ongoing emergence of the world through specific relations and how this emergence is constrained and enabled by specific relations*. These ideas are imperative in the following sections where the discussion focuses on why certain subjects and meanings were desired (enabled), whereas others were not (constrained). Below, examples of desired and undesired boundaries in the empirical case are given and discussed. These are related to material-discursive practices and how these practices determine what is (un)desirable. This also sheds light on why some designs are considered impossible. The general argument in this section is that material-discursive practices enact the world in specific ways as they produce certain boundaries. These constrain and enable what can be said, done and what can come into being – that is, what can be designed.

Material-discursive practices that define what it means to be an (un)fit driver

What it means to be an (un)fit driver is not only defined by the apparatuses and practices described in the empirical case. Instead, this boundary is enacted in different ways by several material-discursive practices. Although the topic and analysis of how the meaning of (un)fit driver comes into being could be a thesis on its own, a few examples of material-discursive practices will be given to illustrate why only specific enactments of (un)fit driver were desired in the empirical case. To do this, we take a historical detour to investigate different enactments, but rest assured that this detour will lead us back to the question of why it is difficult to design innovative IT. This section focuses on the word ‘driver’, whereas the question of ‘fit’ and ‘unfit’ is discussed in section 5.6.1.

A driver is a person engaged in driving, i.e. the activity of operating and maneuvering a motorized vehicle with wheels (“Driver,” 2017; “Driving,” 2017). Before the invention of the car, however, a driver was someone with the occupation of driving working animals (“Driving,” 2017), i.e. the term was defined differently in this specific material configuration or practice. This illustrates Barad’s (2007) argument that concepts are defined and become meaningful by their physical arrangements. Today, however, the concepts of driver and driving are defined by the physical arrangement of the car, rather than by animals (even though horsepower still remains as an animal legacy). For instance, the steering wheel is

essential to become a driver since the driver uses this to operate and maneuver the vehicle, i.e. the wheel is connected to the tires and to the trajectory of the car. Thus, a core part of being a fit driver is to successfully operate the wheel, steer the car and keep it on the road. Steering wheels have been used in cars since the end of the 19th century, but before that, tillers were used (“Steering wheel,” 2016). Accordingly, at one time in history, the subject driver was partly enacted by the physical arrangement of tillers. These examples illustrate how the meaning of driver comes into being through specific material-discursive practices and physical arrangements, e.g. animals, cars, steering wheels and tillers. These material-discursive practices then constrain and enable “what counts as meaningful statements” (Barad, 2007, p. 146), i.e. what boundaries are desirable (possible) or undesirable (impossible).

In the empirical case, this was noticeable since the design of the steering wheel and how realistic it was, were important aspects to enact the (un)fit driver. With a risk of stating the obvious, it would not be possible to design a test with working animals or tillers to enact the subject driver – this would not make sense in the current material-discursive practices. But neither was it possible to design a steering wheel that did not resemble the physical arrangement of a realistic wheel as we know them today. That is, a steering wheel in a car does not float, is not a windshield and has some resistance in it. Hence, it can be argued that the subject driver was coming into being in entanglement with the specific physical arrangement of the steering wheel. Other designs could have enacted the subject driver in another way, but this would not have been in line with the prevailing discourse (or material-discursive practices) that currently define the meaning of driver. Hence, the prevailing discourse of car driving and driver constrained and enabled certain enactments of this boundary which made some enactments desirable and others undesirable. Accordingly, it was not simply the ideas or wills of the clinic or participants that decided what was desirable or not, but rather, this was determined by material-discursive practices of car driving in which the subject driver comes into being. To conclude, to enact ‘driver’ as desired in the test means to enact this subject in line with the prevailing material-discursive practices that define what it means to be a driver.

Material-discursive practices that define what it means to be a patient

As concluded above, the test also had to enact able patients. But why were some enactments of patient desirable and possible whereas others were not? By examining how the meaning of patient is enacted by material-discursive practices, we can gain an understanding of why some enactments were considered impossible (undesirable). Again, we take a historical detour, this time to the material-discursive practices of person-centered healthcare, which helps us understand why the subject patient had to be enacted in a specific way.

Being a patient comes with several disadvantages. First off, patients have an existential disadvantage in that they come in contact with healthcare because of their failing health – a position of suffering and vulnerability. Furthermore, patients are institutionally inferior in the sense that they are at the bottom of a well-established hierarchy and they also have a

disadvantage in terms of knowledge, compared to professional knowledge and advanced medical assessment apparatuses used (Kristensson Ugglå, 2014). One reason for the patient's historically weak position is medicine's focus on scientific measurements. For centuries, healthcare professionals' only tools were close observations – to touch, watch and listen to the patient. However, during the 17th and 18th centuries, medicine turned more towards natural sciences and mathematics which entailed measurements of the body. This also changed the relationship between the healthcare professional and the patient, making it less important (Ekman et al., 2014). Medicine as a scientific endeavor meant that the body had to be studied as an object in which medical scientists tried to isolate and understand pathologies. This led to more impersonal observations of the body by means of medical apparatuses and measurement equipment. The body was seen as an object which could be reduced to numbers. This also entailed a narrow focus, e.g. on a small part of the body such as a heart or a leg, where the wider context was bracketed out. Accordingly, the experiences of the patient became less important or even neglected. This also led to the separation of medicine, with its focus on measuring, diagnosing and treating, from the practices of nursing, with its focus on caretaking (Kristensson Ugglå, 2014). During the 20th century, this separation was questioned by the social sciences and a holistic view of the patient was advocated (Ekman et al., 2014). Accordingly, the patient's position and relation to health professionals have changed through the ages. Today, as a countermovement against the objectivized view in which the patient is reduced to a body, person-centered healthcare is advocated to balance the asymmetry between patient and health professional (Kristensson Ugglå, 2014).

Person-centered healthcare is also rooted in the ideas of democracy, Human Rights and that all human beings are born free and equal in dignity and rights (Ekman et al., 2014). Many of the principles of person-centered healthcare are regulated by the Patient Act (SFS 2014:821), which aims to strengthen the position of the patient and promote patients' autonomy, integrity and involvement. Person-centered healthcare means that the patient is not reduced to her illness or diagnosis nor considered a passive receiver of healthcare. Instead, patients are seen as independent and capable individuals who are experts on their own experiences (Ekman et al., 2014; Kristensson Ugglå, 2014). This view of the patient opens up for involvement of the patient in the process of planning and carrying out healthcare activities, as stipulated by the Patient Act. Person-centered healthcare also emphasizes that the patient should be seen as a whole person and that her life situation should be taken into account (Ekman et al., 2014; Kristensson Ugglå, 2014). This includes to focus on the patient's abilities, individual circumstances, needs, feelings and preferences (Hedman, 2014; Patient Act, SFS 2014:821). This view of patients opens up for a partnership and cooperation between health professionals and patients where dialogue, shared decision making, mutual understanding and respect are key aspects. This also entails that power is shared between the two parties, even though the patient has the last word if agreement cannot be reached (Kristensson Ugglå, 2014).

With these material-discursive practices of person-centered healthcare as a background, it is easier to understand why the patient had to be enacted as *able*. A design in which the patients feel scared, unable, motion sick, treated unfairly or do not understand the test, would collide with the ideas and values of person-centered healthcare. Similarly, if the patients feel that they cannot participate in taking the test properly because of poor maneuverability, e.g. due to that the device has to be maneuvered with two hands or by their feet (pedals), this would violate the ideas of everyone having the same rights to healthcare regardless of potential disabilities. Healthcare should be adjusted to the patient's individual circumstances and preconditions, as required by the person-centered healthcare discourse. To design a test where the patient is enacted as unable does not resonate with the attitudes and approaches practiced in healthcare and by health professionals. As person-centered healthcare builds on the ideas of democracy, Human Rights and Swedish law, such a design would break with these discourses. Accordingly, to design a test in which patients feel unable, helpless or don't understand the healthcare processes are considered undesirable and impossible due to these broader material-discursive practices. Hence, one reason why it is difficult to design innovative IT is that the design has to enact subjects in accordance with these 'larger' material-discursive practices.

In summary, to enact the patient 'as desired' is defined by a set of material-discursive practices including practices and apparatuses used in e.g. medicine, social sciences, democracy, Human Rights and laws (and more – this is not a comprehensive list). In these practices, it is not desirable to view the patient as passive or to bracket out their experiences, but vice versa, to involve them and make them understand in order for them to participate in the decisions about their health. Hence, these material-discursive practices were a part of constraining and enabling what could be designed in the empirical case.

Material-discursive practices that define what it means to be a health professional

The test also had to enact the able health professional. At the core of being a health professional lies the abilities to study, diagnose, treat and prevent illnesses and injuries in patients. These abilities are acquired through material-discursive practices such as education and practical experience and only those who pass the tests of a medical degree may receive a license that allows them to practice their profession. This license functions as a guarantee that the licensee have the proper knowledge, skills and approaches to conduct medical work, including operating medical equipment for diagnosis and treatment. In this sense, the assessments and tests in medical education are examples of boundary-making apparatuses, i.e. they draw a boundary between who is a health professional and who is not.

As mentioned earlier, one important aspect of becoming an able health professional was to help the patients feel able. This is in accordance with the material-discursive practices of person-centered healthcare. Thus, to design a test in which the health professional could not help, instruct or communicate with the patient was considered impossible and undesirable since this would break with the material-discursive practices of person-centered healthcare. Furthermore, the able health professional had to be able to explain and communicate

the test results in a pedagogical way to the patient. Hence, a report with visualizations were preferred by the clinic. This was also in line with person-centered healthcare, i.e. that the health professional informs and educates patients so that they can participate in their healthcare and make informed decisions (Ekman et al., 2014). Accordingly, to design a test where health professionals are inhibited from doing so is impossible since it collides with the prevailing material-discursive practices of e.g. person-centered healthcare. Hence, the design of the test results had to be easy to understand. Yet, at the same time, it could not be oversimplified. To oversimplify the visualizations, as in the suggested design with green, yellow and red colors, was problematic. As mentioned above, this design did not enact the able health professional as desired. Rather, this physical arrangement would ‘hand over’ the power of determining who was a fit driver or not to the test. That is, getting a green light on the test would indicate that the patient was a fit driver, regardless of the health professional’s observations and qualitative assessment of the patient. Accordingly, the clinic opposed this design of the test results since they wanted the power to determine (i.e. the agency to draw the boundary) between fit and unfit drivers to remain with the health professional.

This example shows how agency is relational. As mentioned in the theoretical foundation, in agential realism, agency emerges and shifts in various physical arrangements (Barad, 2007; Orlikowski, 2007; Orlikowski & Scott, 2008). The specific physical arrangement of the report with green, yellow and red lights illustrate how agency (in this example; the power to determine between fit and unfit driver, i.e. the power to make a difference in the world) emerges and shifts with the specificity of the arrangement and, thus, how even small details in an artifact’s design can lead to shifts in agency.

Since the clinic wanted the agency to stay with the health professionals, they opposed this specific design of the results. Had they accepted the design with three different colors, the subject able health professional would have had to be redefined. What was the role and meaning of the health professional if it was not to distinguish between who was (un)fit to drive and to explain this to the patients? The health professional would no longer be as important in the enactment of the subject (un)fit driver. Their tasks would rather be to simply operate the test – to push the start button. Accordingly, this would not be in line with the prevailing material-discursive practices of person-centered healthcare and the practices that defined the meaning of health professional. This specific design of the results were considered impossible since it would entail a shift in the distribution of agency and what it means to be an able health professional, i.e. it would enact the health professional in an undesirable way that was not in line with prevailing discourses.

Accordingly, the design of the report had to help the patients feel able, i.e. make them understand the results so that they could actively participate in their healthcare, but also make sure that the agency of the health professional was not diminished. Or put differently, the increased power to the patient should not come at the expense of the power of the health professional. As mentioned above, the (un)fit driver could only be produced in entanglement with the health professional, i.e. the health professional determined who was

fit to drive or not. In summary, to enact the able health professional as desired meant to design both the test and the results in line with prevailing material-discursive practices which also meant that agencies were *not* to shift.

Material-discursive practices that define one-sided brain injuries

Finally, we will examine why some enactments of one-sided brain injuries were desired and possible and others not. Above, it was concluded that a too narrow angle in the test design would be impossible since it would not enact one-sided brain injuries, i.e. it would not enact the brain as divided into two hemispheres. Hence, a wider angle was needed. That is, that the brain is divided into two hemispheres and that the left hemisphere is connected to the right-hand side part of the body (known as lateralization of the brain) and vice versa, made a narrow angle impossible. This understanding of the hemispheres constrained what was possible to design. But this understanding or knowledge is not given, but enacted.⁴ But what was this idea based on? To illustrate this, we have to consider the apparatuses enacting this taken-for-granted boundary which leads us to take a small detour in the field of neuroscience.

First off, how do we know that the brain is divided into two parts? One way in which we know this is through the practices of dissection of the brain, which have taken place throughout history. That is, the brain has to be cut out and ‘revealed’ for the two hemispheres to become visible. Hence, without this practice we would not know the shape of the brain (at least if there are no other apparatuses to study the brain). Furthermore, the hemispheres look very similar to each other (“Cerebral hemisphere,” 2017), so the next question is – how do we know that the hemispheres control the opposite side of the body? One way in which we know this is through neurosurgeon Wilder Penfield’s and neurologist Herbert Jasper’s work in the 1940s. In their studies of brains, they stimulated one of the hemisphere’s motor cortex with small electrical currents and found that this produced muscle contractions on the opposite side of the body (“Lateralization of brain function,” 2017). Hence, the connection between the hemispheres and the body was enacted with the apparatuses of their research, including brain surgery, electrical equipment and observations of responses, to name but a few.

Other apparatuses that help enact the brain as divided into two hemispheres include imaging technologies such as fMRI (functional magnetic resonance imaging) and PET (positron emission tomography) scans. The main point here is that the brain as divided into two hemispheres is produced in a multitude of material-discursive practices, i.e. through specific apparatuses, and that other apparatuses could enact the brain in other ways. This does not mean that the brain can be enacted in any way possible, or “by the dint of our own will”, as Barad (2007, p. 353) puts it, but that apparatuses include certain things (i.e. the brain as lateralized) and, thus, exclude other possible enactments of the brain. This can

⁴ This does not mean that this enactment is questioned or doubted, but rather just a reminder that all matter and meaning are coming into being in material-discursive practices and are not pre-existing or given – even those which we might take for granted.

be compared to Barad's example of how light is enacted as either wave or particle, exclusively.

To illustrate the enactments of the brain's materiality and meaning, one more example is in place. For decades, it has been known that the lymphatic system exists in all body parts except for the brain. However, in 2015 scientists found that there are lymphatic vessels in the brain as well (Louveau et al., 2015). How come these researchers found these vessels after all these years of neuroscience? They used different methods than had been used before ("Meningeal lymphatic vessels," 2017). That is, the lymphatic vessels in the brain were enacted – became determinate and defined – only in intra-action with a specific apparatus. This 'discovery' made the scientific community exclaim that the textbooks need to be rewritten, i.e. the knowledge and long-held truth of the brain and the lymphatic system had to be revised. This also raises the question of what other things and meanings are not enacted since current apparatuses exclude them. With another set of apparatuses, the brain or other 'entities' may be enacted in different ways.

This is a helpful example since it illustrates how material-discursive practices and discourses constrain and enable what can be said, what can come into being and what counts as meaningful statements (Barad, 2007). Before 2015, it would not have been possible or made sense to speak of and study the brain as part of the lymphatic system. But after these studies, studying the brain's lymphatic vessels is suddenly possible and reasonable. Hence, the new methods (i.e. the apparatuses) used by the researchers redefined the constitution of the human body and, hence, what is considered meaningful in terms of matter and meanings of the body.

The point here is not to get stuck in details of neuroscience and medical research practices of the brain but to highlight that the brain's division and lateralized functioning (both in terms of matter and meaning) are produced by several apparatuses. They are not pre-given but continuously come into being in intra-actions with multiple apparatuses. This specific enactment of the brain constrains how the test can be designed in terms of angles. Thus, the material-discursive practices that produced the lateralized brain are also a part of producing the (im)possibilities of the test design. That is, the way the world is enacted entails some possibilities and some impossibilities – it entails inclusions and exclusions. For instance, to talk about the brain as *not* divided into two hemispheres does not make a meaningful statement in the medical discourse. It would be considered 'nonsense' or impossible and, accordingly, the material-discursive practices described above are affecting what is possible to design. That is, that the medical discourse enacts the brain as divided into two hemispheres has implications for the test design, i.e. the screen cannot be too narrow since this makes it impossible to discriminate between the hemispheres. Hence, when stating that the impossible designs would not enact one-sided brain injuries as *desired*, what is meant is that this design would not produce boundaries (subjects, objects and meanings) that are in line with the prevailing material-discursive practices. Instead, the design has to produce similar boundaries as those enacted by the medical practices.

5.4.8. Summary of defining what is desirable

The previous sections have been lengthy and full of examples and details. For this reason, it is suitable to summarize what has been stated so far. The aim of the sections was to investigate why some enactments of subjects and meanings were undesired and, thus, why some designs were impossible. This can be broken down into three points:

1) Material-discursive practices enact the world in specific ways.

Several examples have been given of how material-discursive practices produce boundaries, matter and meaning. In this sense, these practices are continuously producing the world in specific ways – they determine and define matter and meaning.

2) Material-discursive practices constrain and enable what can be designed.

Material-discursive practices produce the world in specific ways and define matter and meaning and, thus, affect what can come into being. This means that the practices enable specific enactments of boundaries, i.e. these enactments are considered meaningful and are in line with the existing or prevailing material-discursive practices. That is, material-discursive practices determine what counts as meaningful statements and what can come into being – what is considered desirable or not. But this also means that other enactments of matter and meaning are excluded. They are not considered meaningful and are *not* in line with the material-discursive practices. For instance, the impossible designs described above enacted different boundaries which meant that other meanings were produced, i.e. meanings were redefined in undesired ways. That is, the material-discursive practices include certain enactments and exclude others.

In this sense, material-discursive practices determine what boundaries (matter and meaning) that are meaningful and which are desired. This excludes other enactments and constrains what can be said, done and what can come into being – what can be designed. This is why some enactments are impossible. These enactments *are not in line with the existing material-discursive practices*. Vice versa, the material-discursive practices include specific enactments and enable certain enactments of matter and meaning. Designs that enact boundaries that are *in line with the existing material-discursive practices are possible*. To enact the subjects and meanings as desired means to design *within the material-discursive practices*, whereas undesired and impossible enactments *deviate from or break with the existing material-discursive practices*.

3) Material-discursive practices are agential.

That material-discursive practices enact the world in specific ways and, thus, constrain and enable what can come into being means that they make differences in the world – they are agential (Barad, 2007). This also helps explain why more innovative designs (and by that, enactments of other matter and meanings) could not be introduced to the existing material-discursive practices. For instance, the physical arrangement of the report with green, yellow and red lights did not have the agency to disrupt the practices that enacted the able health professional. These material-discursive practices included medical education and licenses, person-centered healthcare and Swedish law (such as the Patient Act). Hence, these practices had more agency in defining this subject than did the physical arrangement of the

report. In this sense, these practices were not easily susceptible to change or redefinition. The physical arrangements of the impossible designs did not have ‘enough’ agency to redefine the material-discursive practices or enact the world differently, thus, they were excluded. Agency is discussed further in section 5.8.

Summary: To enact a boundary as desired means to enact it in line with existing material-discursive practices, whereas undesired boundaries are *not* in line with existing practices. Material-discursive practices are agential since they determine what boundaries can be enacted or not.

5.5. Possible designs

The previous section concluded that some designs were impossible since material-discursive practices constrained what could be designed. This section focuses on possible designs and why these designs were considered possible. Two types of possible designs are discussed. First, designs that were similar to the old driving simulator is examined, followed by a discussion on more ‘novel’ designs that did not resemble the old driving simulator.

5.5.1. Designing similar configurations

As noted both in the empirical chapter and also in the descriptions of the configurations above, many design features of the old driving simulator and the new test were similar. The clinic preferred that the new test had a similar technological setup to that of the old driving simulator, including a similar screen, road, steering wheel and tasks. Why were these designs preferable rather than to design a test that would be considered more ‘new’ or ‘innovative’?

As noted above, Barad (2007) argues that if the apparatus changes, there will be corresponding changes in the observed phenomenon. Hence, if the design of the test is changed it will not enact similar subjects and meanings but the boundaries will change. Or put differently, making the design of the new test similar to that of the old driving simulator would help enact similar boundaries. This can be illustrated by the participants’ discussions about the need for a realistic steering wheel. Here, the clinic thought that the laptop solution was most suitable since it included a fixed steering wheel that could only be turned to the right and left and was separate from the screen. This setup, which was found in the old driving simulator and the laptop solution, would help patients understand and accept the test’s relevance for car driving. Thus, this specific design of the steering wheel enacted the (un)fit driver as desired. This setup would also make it easy for patients to maneuver the steering wheel, regardless of if they could use one or two hands, enabling patients to feel competent when taking the test. Hence, this specific configuration would also help enact the able patient as desired. The setup also enabled the health professional to view the screen and instruct the patients during the test and, thus, enacted the able health professional as desired. To conclude, by using a design similar to that of the old driving simulator’s steering wheel, the new test would help enact similar subjects.

Likewise, by using similar tasks in the new test, the cognitive (dis)abilities would be enacted in similar ways as in the old driving simulator. Hence, the meanings of attention, reaction, processing ability and simultaneous capacity were enacted in a similar fashion as in the old driving simulator by mimicking both the technological setup and the tasks to a great extent. For instance, both of the tests entailed tasks where the patients were to press the right or left button on the steering wheel as quickly as possible when stimuli appeared on the right or left side of the screen. Also, stimuli were shaped as arrows to enact processing ability in the same way as the old driving simulator. That is, other configurations such as stop signs or warning signs were not possible since they would have enacted this cognitive (dis)ability differently. That is, the physical arrangements (designs) of the tests were similar in that they included arrow-shaped stimuli on the screen, buttons on the steering wheel and numbers in the report (e.g. reaction time, correct responses, missed stimuli). Accordingly, the participants designed a setup similar to the old test to measure (enact) the cognitive (dis)abilities in the same way as before. Or put differently, by designing a similar test (apparatus), similar subjects and meanings (boundaries) would be enacted.

5.5.2. Possible new designs

In many ways, the design of the new test resembled the old driving simulator. However, there were also some design features that were not the same as or similar to the old driving simulator. Hence, some more ‘novel’ designs were possible. This raises the question why it was possible to design some things differently. This is discussed in the following sections.

Practice

A difference in the design of the old driving simulator and the new test was the amount of practice. In the old driving simulator, all patients got to practice for two minutes, but this was not always enough for them to get acquainted with the steering wheel or to understand the task. The clinic preferred if the health professionals could adjust and individualize the amount of practice to the patients rather than having a fixed amount of practice in the test. In this way, the patients were to take the actual test first when the health professionals thought that they had practiced enough, i.e. that the patient understood the task and had learned to maneuver the steering wheel – when they had become able patients.

Consequently, a design in which the practice parts were adjustable and possible to individualize helped the health professionals make the patients feel able. Without the practice parts, the health professionals were left with only using verbal instructions which the clinic argued was not enough to make some patients understand the tasks. Hence, the design of adjustable practice parts helped health professionals to communicate with, instruct and help the patients to make them feel competent when taking the test. This is in line with the material-discursive practices of person-centered healthcare which emphasizes the patients’ involvement in their healthcare and that they are well-informed and feel able. Hence, this change in the design helped the health professional enact the able patient in a way that was in line with the material-discursive practices of person-centered healthcare. Or put differently, this design enabled the enactments of the able patient (and by extension, the (un)fit

driver) and able health professional more successfully than a design with little or no practice. Accordingly, this design differed from the old driving simulator but was still considered possible as it *strengthened* the enactments of these subjects and was in line with existing material-discursive practices. In this sense, these practices enabled certain enactments.

Practice also played an important part in determining the cognitive (dis)abilities. By letting the patients practice until they felt able, the health professionals could become more certain that they actually measured the patients' cognitive (dis)abilities. That is, through practice, the health professionals could determine if the patients understood the tasks, i.e. that they not only guessed what they were supposed to do, and that they could maneuver the steering wheel properly, i.e. that the results did not only reflect their inability to maneuver the test. Hence, increasing the amount of practice contributed to that the cognitive (dis)abilities were enacted as unambiguously as possible (cf. section 5.4.4.). In this sense, practice helped exclude potential measurement errors and irrelevant variables (such as patients' inability to understand the test task), making the results less ambiguous. Accordingly, this change did not only contribute to enacting the subjects in line with existing material-discursive practices but it also enacted the meanings of the cognitive (dis)abilities in line with existing measurement practices (these are discussed in section 5.6.2.). Put differently, the change in the design was possible since it enacted the boundaries in line with existing material-discursive practices.

Visualizing the hood of the car

Another example of a possible design that differed from the old driving simulator was to make the patients see the hood of the car. The clinic argued that it was advantageous if the patients could see how the car related to the road. Even though this was unrealistic in the sense that it did not mimic a real car driving experience, it helped the patients show their abilities. If they did not see the hood, they did not know how well they kept the car on the road and, thus, they felt that potential failures were because of this rather than due to their impaired cognitive abilities. Hence, to see the hood of the car was unrealistic but the clinic still preferred this solution as it both helped the patients feel able when taking the test and, thus, helped them accept the test and the results, enacting the subjects able patient and (un)fit driver. To enact these subjects was of greater importance than to mimic an authentic car driving experience. Hence, it was possible to change the design if this change helped enact the subjects as desired, i.e. in line with existing material-discursive practices.

Test results

One of the major changes in the new test was the design of the test results. The report of the old driving simulator was hard to understand and interpret why the clinic preferred a pedagogical report with visualizations. In this way, that health professionals could explain the test results to the patients and make them understand and accept them, i.e. enact the able patient and (un)fit driver. This was in line with the material-discursive practices of person-centered healthcare, where it is important that the patients can take part of information about their health and healthcare. For instance, the Patient Act (SFS 2014:821) states

that health professionals should adjust the information to the patients and should, as far as possible, ensure that the patients have understood the information. This was done in the report of the new test in the sense that the information was presented in a way that was easy to understand.

Another aspect of person-centered healthcare is that in cases where patients' abilities to communicate are inhibited, including difficulties to speak and understand due to e.g. stroke, neurological diseases or traumatic brain injuries, verbal communication has to be adjusted and complemented by e.g. gestures, images, visualizations and objects (Saldert, 2014). This explains why the clinic repeatedly mentioned the importance of being able to *show* the patients how they did, as this would complement the verbal explanations. For instance, by visualizing the results and using films from the test, the health professionals could give instant feedback and show the patients how they drove or failed to respond to stimuli. Similarly, by enabling patients to *see* how they performed, e.g. if they reeled from side to side on the road, missed stimuli or to watch a normal distribution in which the patients could compare their results to normal or deviant performances, the patients would have an easier time to understand if they were fit to drive or not. The clinic hoped that patients could be 'awoken' and convinced by watching their own performances. That is, patients with brain injuries who had a hard time to take in new information and who did not understand that they had cognitive impairments that made them unfit to drive, could come to such an understanding by seeing how much they e.g. reeled on the road or missed stimuli. Accordingly, changing the design of the report would help in the enactment of both the (un)fit driver and able patient. These enactments were in line with the material-discursive practices that defined these subjects (as discussed and exemplified in section 5.4.7.), i.e. they were enacted as desired.

Hence, the report had to help enact the able patient and the (un)fit driver as desired and thereby also contribute to the enactment of the able health professional. That is, a more pedagogical report would give the health professionals tools to help the patients understand and accept their potential cognitive impairments, i.e. this type of design would be more helpful in enacting the able patient and (un)fit driver than if they had to only rely on verbal communication. That is, verbal explanations and tables of numbers on a report sheet were argued to be less effective in creating understanding than visualized and graphic results. Furthermore, the report had to be designed so that these enactments were in line with existing material-discursive practices. It had to enact the able patient in line with person-centered healthcare but it could not be too simplified since this would shift the agency of the health professional (as discussed in section 5.4.7. and 5.8.). To conclude, changes could be made to the design of the report as long as the subjects were enacted as desired, i.e. in line with existing material-discursive practices which constrained and enabled what subjects could be enacted.

Cognitive (dis)abilities

The new test enacted processing ability in a similar way as the old driving simulator, i.e. through a task where patients were to distinguish between if the arrows pointed to the left or to the right. However, the clinic also added another task; to *not* react to arrows pointing left. By suppressing reactions to these stimuli, the clinic argued that they could assess if patients could process stimuli and then choose *not* react to all stimuli, i.e. if the patients could distinguish between when to react or not. In a similar fashion, the enactment of cognitive load was also changed in the new test. The new configuration included a curvy road with different speeds instead of a straight road with one speed and simulated wind. Accordingly, it was possible to change the design somewhat and still enact processing ability and cognitive load as desired. How come these new designs were possible when many other new designs were considered impossible? Does not changes in the apparatus lead to changes in the observed phenomena, as Barad (2007) argues?

One way to explain this is that these designs did not alter or redefine the meaning of processing ability and cognitive load to any greater extent. They were enacted somewhat differently, but these enactments were in line with existing material-discursive practices of cognition and medical knowledge. They did not break with these practices or redefined the meanings. Hence, these changes were possible since they contributed to enact these boundaries as desired, i.e. in line with the material-discursive practices. Furthermore, the design which enacted cognitive load also contributed to the ecological validity, making the test more similar to a real car driving situation and, thus, helped enact the (un)fit driver. Accordingly, it was possible to redesign the new test somewhat if the design contributed to the enactment of the desired boundaries.

5.5.3. Summary of why some designs were possible

In the discussion above, it was concluded that designs that were similar to the old driving simulator were possible since these designs enacted similar subjects and meanings as the old driving simulator. It was also concluded that designs that were more ‘novel’ and that did not resemble the old driving simulator were possible if these designs enacted the subjects and meanings as desired, i.e. that the enactments were in line with the existing material-discursive practices that constrain and enable what is meaningful. Changes in the design that did not redefine, break with or challenge these practices were possible. More novel designs were especially viable if they contributed to the enactments of the subjects and meanings in line with these practices and thereby helped strengthen these specific boundaries.

Summary: Designs that were similar to preceding designs were possible since they enacted similar boundaries. More novel designs were possible if they enacted boundaries that were in line with existing material-discursive practices.

5.6. Uncertain designs

The previous sections examined why some designs were impossible or possible. But there were also designs that were uncertain, where the participants did not know what boundaries the design would produce and, thus, if the boundaries would be enacted as desired. This included queries such as which designs would cause motion sickness, the angle of the screen to be able to assess one-sided brain injuries, if the design of the primary task would be difficult enough to cause a cognitive load, and if they really measured patients' (un)fitness to drive. This section focuses on why some designs were uncertain and how the uncertainty was managed.

5.6.1. Why some designs were uncertain

As has been mentioned several times, motion sickness was a problem since it inhibited the enactment of the able patient and made the measurements of the cognitive (dis)abilities ambiguous. However, it was not straightforward when motion sickness appeared. A too curvy road, too wide screen and encapsulation were considered plausible causes of motion sickness, but the VTI researchers pointed out that there were examples where motion sickness occurred even with straight roads or when the driver had clear points of references in the room. Accordingly, it was uncertain exactly when and why motion sickness occurred – knowledge about this was lacking. Put in agential realist terms, it was unclear what specific material configurations that produced motion sickness.

Similarly, there was a knowledge gap on how fitness to drive should be assessed. As mentioned in the empirical chapter, there was no established norm or practice for assessing this. Many aspects could make a person more or less fit to drive, including their cognitive (dis)abilities, judgment and risk assessment in traffic, driving experience, personality, self-awareness and ability to adapt their driving to their (dis)abilities and circumstances. This list can be extended with aspects such as medical requirements, e.g. eye tests to examine the driver's eyesight and certificates stating that the driver does not have any diseases that would make them unfit to drive. Fit drivers also needed to be able to maneuver the vehicle and adhere to traffic rules which both require knowledge and skill. The participants concluded that determining fitness to drive was a complex task and that a clear definition of fitness to drive was lacking in the available research and knowledge on the topic. Accordingly, to design in this knowledge gap was a major uncertainty for the participants. Put differently, it was unclear what specific configurations or material-discursive practices that enacted (un)fit driver unambiguously. This can be compared to more certain boundaries, e.g. the material configurations needed to determine the able health professional. Here, the clinic knew how the test should be designed to enact this subject in line with existing material-discursive practices. However, in the cases of the uncertain designs, such clear material configurations were missing.

Since (un)fitness to drive was difficult to define and assess, the participants decided to focus on cognitive (dis)abilities that had been shown to correlate with people's fitness to drive and that also could be compromised by brain injuries, i.e. attention, reaction, simultaneous

capacity and processing ability. However, also these were difficult to define unambiguously, i.e. it was unclear what specific physical arrangements were needed to determine them. For instance, what exact angle was needed to be able to distinguish between the hemispheres, i.e. what screen width was needed and how far from the screen could the patient sit? The clinic concluded that the knowledge about one-sided brain injuries did not specify any exact angles where neglect occurred or not. Similarly, it was uncertain when a reaction was so slow that the patient was considered inattentive or having processing deficiencies. The clinic argued that clear thresholds discriminating between those who were fit to drive or not did not exist, since it was a new test. Accordingly, there were no material-discursive practices that made this boundary determinate, and thus, it was uncertain and ambiguous.

The same can be said about the enactment of the cognitive load. Here, it was uncertain if the test was difficult enough to create a cognitive load for every patient. What specific configuration was needed to enact cognitive load, i.e. how curvy should the road be, what velocity was needed, for how long should the patient drive? A specific configuration was needed where the speed was neither too fast, nor too slow. A too rapid pace could make the test too difficult whereas a slow speed would not challenge the patients. Hence, the specificity of the configuration was key to creating a cognitive load for every patient. Similarly, the duration of the test was important to create a cognitive load. The clinic was not sure how long the test had to be to achieve this, but they pointed out that some patients managed to concentrate successfully for some time but then became tired and started to make mistakes. Accordingly, it was unclear what specific physical arrangement was needed to enact cognitive load.

In summary, some designs were uncertain since the participants did not know what boundaries the new configuration of the design would produce. This can be described as knowledge gaps, i.e. there were no existing material-discursive practices or established configurations that determined when e.g. motion sickness and the different cognitive (dis)abilities were produced. Since it was important that the test enacted these boundaries as desired, i.e. in line with existing material-discursive practices, the uncertainty had to be managed in some way. This is discussed in the next section.

5.6.2. How the uncertainty was managed

The uncertainties described above were managed in two ways. The participants mimicked how the measurements (enactments) had been done before and also argued that the test had to be empirically evaluated to ensure that it measured what it claimed to measure. That is, by evaluating the test empirically, they would control that the boundaries were enacted as desired, i.e. in line with existing material-discursive practices. This is discussed in the sections below.

Mimic existing material-discursive practices

As mentioned above, the participants were sometimes uncertain about what boundaries the new test would enact. To avoid this uncertainty, they often mimicked existing physical

arrangements which they knew enacted certain boundaries. For instance, to avoid the uncertainty of motion sickness, the participants mimicked the traffic environment of the old driving simulator. By making the environment simple and stylized in a similar fashion as the old test, the clinic argued that it was unlikely that patients would get motion sick when taking that test. They also followed the advice of the VTI researcher and avoided too curvy roads and large screens, hoping that a similar design would enact similar boundaries. In this way, a more novel design was inhibited. Similarly, the participants also mimicked the design of the old driving simulator to enact the cognitive (dis)abilities in a similar way as had been done before.

By mimicking existing physical arrangements, the new test reproduced boundaries which aligned with existing material-discursive practices. For instance, how cognition was enacted in the case is in line with a long tradition of cognitive psychology. Our modern understanding of cognition and cognitive (dis)abilities build on research in cognitive psychology from the 1950s. During this time, cognition was construed as information processing and was inspired by information theory, linguistics and the development of computers during World War II (Smith, 2001). Researchers used the computer as a metaphor for human cognition, i.e. that humans processed information as a computer, including selection, storage, reception and manipulation of information. For instance, drawing on the assumptions of cognition as computation (i.e. that the cognitive system's capacity to process information is limited and that cognitive processes take time) lead to the idea that response times were considered an appropriate measure of cognitive processing (Frensch, 2001). In this method, known as *mental chronometry*, people perform perceptual-motor tasks. That is, they are presented with stimuli (often visual or auditory) and are asked to respond as quickly as possible by e.g. pressing a button, responding verbally or performing other observable behaviors. The results are used to infer the temporal sequencing, content and duration of cognitive processes ("Mental chronometry," 2017). Hence, this builds on the assumption that measuring people's reactions to stimuli says something about their abilities to process information (Frensch, 2001). Accordingly, by mimicking the designs and measurements used in the old driving simulator, the participants adhered to this long tradition of how cognition have been enacted throughout history. In this sense, the design can be seen as historically embedded. The tests in the case can be considered a type of mental chronometry in the sense that the patients are presented with stimuli and are to react by pressing a button. Their cognitive (dis)abilities are then assessed in terms of reaction times and correct responses.

Furthermore, the assumption that the brain operates in the same way as a computer is part of the apparatus enacting cognition. By following these lines of thoughts and mimicking the old driving simulator, these assumptions and boundaries are reproduced. In this sense, by mimicking the old design and adhering to existing enactments of cognition, the design was in line with prevailing material-discursive practices. That is, they designed *within* the discourse which meant that the boundaries were not changed or redefined but rather reproduced.

Here, it is useful to point out that cognition is enacted in different ways in different practices. There are many other physical arrangements in which cognition is defined, e.g. apparatuses that measure eye movements and tests where participants are to recall information (Frensch, 2001) or copy complex figures (Uekermann & Daum, 2001). Other apparatuses are neuroimaging techniques such as fMRI, PET scans and EEG (electroencephalogram), which measure e.g. electrical activity and changes in cerebral blood flow. Hence, these technical advancements (physical arrangements) have enabled different enactments and understandings of cognition. The point here is that apparatuses do not simply ‘measure what is already there’ but produce specific boundaries. In this sense, cognition and cognitive (dis)abilities are defined in specific material-discursive practices. This also means that, by mimicking the old driving simulator, the design of the new test reproduced boundaries as they are enacted by mental chronometric material-discursive practices. Accordingly, by mimicking the old driving simulator, the participants diminished the risk that cognition would be enacted in an undesirable way. Hence, they designed within prevailing material-discursive practices to avoid uncertainty regarding what boundaries would be enacted.

Furthermore, in their design to create a cognitive load for the patients, the participants also designed *within* prevailing material-discursive practices to avoid uncertainty. They mimicked the old driving simulator by using a primary and secondary task. By doing so, they also adhered to a material-discursive practice that enacted cognitive load in a specific way, known as dual task analysis in which people perform two tasks simultaneously and their performance outcomes are measured and analyzed (Brunken et al., 2003). In this sense, the design reproduced the boundary cognitive load through a similar material-discursive practice.

Due to the uncertainty about what angles were needed to enact one-sided brain injuries as desired, the participants first mimicked the traffic constitution which stated that drivers should have a visual field encompassing 120 degrees. Later, however, they mimicked the old driving simulator. Accordingly, the uncertainty and lack of knowledge about what angles were needed to distinguish between the hemispheres led to that they mimicked previous solutions. Thus, the design was similar to the old driving simulator *to enact similar boundaries* and, in this sense, the design was not very ‘novel’ or ‘innovative’.

In their attempt to find a suitable angle, the participants made estimates and calculated how wide the screen had to be in order not to place stimuli in the central field of view. Here, mathematics were key to defining what was too wide or too narrow, i.e. what was possible to design or not. Also, a medical discourse was important here as it defined how the brain functioned and how it was related to eyesight. Or put differently, the medical discourse was entangled with the mathematical discourse through the material-discursive practices of making the human body measurable (cf. the objectivized body described in section 5.4.7.). Hence, to avoid uncertainty, the participants designed a test that was in line with the discourses and enacted the body and the brain in a similar way as before. Thus, the design did not break with these enactments and were not very innovative.

To summarize, the participants managed the uncertainties and knowledge gaps by mimicking what had been done before and designing *within* these material-discursive practices. Hence, this limited how ‘innovative’ the design could be.

Evaluation of the test’s material configuration

Another way in which the participants dealt with the uncertainty was to evaluate the design empirically. That is, the material configuration of the design had to be assessed in terms of reliability and validity to ensure that it enacted boundaries as desired. For instance, it had to be empirically tested if the configuration of curves, speed, traffic environment, screen size and distance to the screen produced motion sickness or not. Similarly, the amount of cognitive load had to be evaluated to ensure that all patients were exposed to a cognitive load, i.e. how curvy should the road be, what speed should be used and how long should the test be? Accordingly, the specificity of this configuration had to be studied empirically to become determined.

The empirical evaluation was to be performed through a *medical research practice* in which comparative values were to be established. The comparative values were important aspects of the configurations of the cognitive (dis)abilities. These were needed to distinguish between ‘normal’ and ‘deviant’ performances in terms of the cognitive abilities. Without them, the boundary between e.g. attention and inattention – between ability and *disability* – would be ambiguous. Accordingly, the comparative values were essential in the enactment of the cognitive (dis)abilities. In this sense, the comparative values were a part of the apparatus which created certain boundaries, i.e. the boundary between ‘normal’ and ‘deviant’.

Furthermore, there were no predefined or pre-existing boundaries for ‘normal’ or ‘deviant’, no clear guidelines for when a person with impaired abilities was considered an unfit driver – these boundaries had to be made. As the participants discussed the design of the report, the clinic concluded that, since the test was new, it did not exist any clear thresholds between what was considered e.g. a ‘normal’ or ‘deviant’ level of wobbliness, difficulty, response time and so on. They argued that these thresholds had to be created by letting a lot of ‘normal’ people take the new test and in this way determine what was a ‘normal’ performance or not, i.e. creating norm data. Accordingly, the comparative values of ‘normal’ and ‘deviant’ had to be defined in the subsequent research process in which the new test was validated. These values of ‘normal’ and ‘deviant’ would become determinate in the configuration of the accumulated performances of ‘normal’ people taking the test and the mathematical and statistical practices of calculating ‘normal’ and ‘deviant’, e.g. in normal distribution charts. In this sense, the normal distribution had the dual aim of both distinguishing between normal and deviant and also to visualize this in the report. Accordingly, the meaning of ‘normal’ and ‘deviant’ can be defined in a multitude of ways but here, being ‘normal’ meant to not deviate statistically from the average or norm. The meaning of these concepts would be defined in a specific configuration including e.g. ‘normal’ people and their performances, mathematics and statistics. Accordingly, the

configurations of cognitive (dis)abilities also encompassed the specific configuration enacting ‘normal’ and ‘deviant’.

To evaluate normal and deviant cognitive (dis)abilities through research apparatuses such as quantitative methods, statistics, and normal distributions is a legacy from the early days of psychology (e.g. by the beginning 18th century). By then, quantitative methods were adopted in psychology since quantitative physics was held in high regard, i.e. there was a will to measure and quantify cognition (Michell, 2001). This also led to the use of inferential statistics, hypothesis testing, control groups and norm referencing to evaluate experiments (Atkinson, 2001; Dehue, 2001; Frensch, 2001). Accordingly, mathematics is a part of the apparatuses enacting cognition and play an important part in producing the results in experiments. Another way to define ‘normal’ and ‘deviant’ in the new test suggested by the clinic was to run the two tests in parallel. By doing this, the results of the tests could be compared and this could help in interpreting the results and values from the new test, using the old simulator as a guideline. In this sense, ‘normal’ or ‘deviant’ was also defined by the configurations of the old driving simulator.

By using existing material-discursive practices such as medicine and statistics, the participants could ensure that the new design enacted boundaries as desired, i.e. in line with these dominant practices. That is, the uncertainty about what boundaries were performed was diminished by using established medical research practices. In this sense, the test also gained legitimacy from intra-acting with these practices. This is especially important in healthcare where medical equipment and practices are to be evidence-based. Hence, by mimicking and evaluating the design, redefinitions of boundaries and potential divergences from the prevailing material-discursive practices were avoided. However, this also entails a difficulty to design a test that differed from the old driving simulator, impeding innovative design. That is, the participants designed within the material-discursive practices and did not redefine subjects and meanings.

The take-home message here is that the uncertainty regarding what boundaries the new design would enact was managed by evaluating the design through material-discursive practices such as medical research and statistics. In this sense, the boundaries of the new design could gain legitimacy from these evaluation practices.

5.6.3. Summary of why some designs were uncertain

Some designs were uncertain since it was unclear what boundaries the design would produce and, thus, if the boundaries would be enacted as desired, i.e. in line with existing material-discursive practices, or not. To manage this uncertainty, the participants mimicked the old driving simulator to help produce similar boundaries. The uncertainty was also diminished by evaluating the design empirically through statistical and medical research practices. In this way, the participants could ensure that the new design enacted boundaries that were in line with existing material-discursive practices.

Summary: Designs were uncertain if it was ambiguous what boundaries they would enact and, thus, if the design would produce subjects and meanings as desired, i.e. in line with existing material-discursive practices. This uncertainty was managed by mimicking previous designs and by evaluating the new design to ensure that the test would enact boundaries as desired.

5.7. Summary of Part II

Part II has illustrated and discussed why some designs were impossible, possible and uncertain. Designs were impossible if they did not enact several boundaries as desired, i.e. that they deviated from or broke with the existing material-discursive practices, since this would risk redefining subjects and meanings. It was also stated that material-discursive practices enact the world in specific ways and that these constrain and enable what can be designed. This inhibited the possibility to design an IT artifact that differed from its precedent. Designs were possible if they enacted similar boundaries as had been produced before, i.e. were designed in line with the existing material-discursive practices. In this sense, it was argued that material-discursive practices are agential since they determine what boundaries can be enacted or not. Finally, some designs were uncertain since it was ambiguous if they would produce boundaries that were in line with existing material-discursive practices or not. This uncertainty was managed by using existing apparatuses to ensure that the new design aligned with prevailing material-discursive practices.

Summary: Material-discursive practices are agential and enact the world in specific ways. Possible designs aligned with these existing practices, whereas impossible designs deviated from them and produced different boundaries. Uncertain designs were ambiguous in terms of what boundaries they produced and, thus, had to be aligned with existing material-discursive practices to be possible.

Part III – The difficulties of designing innovative IT

The aim of Part III is to discuss the analysis presented in Part I and II in light of prior research about IT design and innovation. This part focuses on why it is difficult to design innovative IT. The agential realist analysis of the empirical material provides a new angle to understand the difficulties to design innovative IT. Here, it is highlighted that IT is both produced and productive. Part III also discusses incremental and radical IT design in terms of aligning with or deviating from existing material-discursive practices. The takeaway message of Part III is that material-discursive practices are agential and enable and constrain innovative IT design.

5.8. IT as produced and productive

The historical retrospectives above illustrated how objects and subjects such as the brain, cognitive (dis)abilities, patients, health professionals and drivers have been enacted in and by different material-discursive practices. These included medical practices, i.e. apparatuses to measure and define the human body (such as equipment, mathematics and statistics), material-discursive practices which defined the agencies of the patient and the health professional (such as Human Rights and person-centered healthcare), and car driving practices (including steering wheel, car gear and traffic environment). These practices were part of defining the old driving simulator and, in this sense, IT is historically embedded and produced. For instance, the design of the old driving simulator aligned with the enactment of the lateralized brain and also with practices of mental chronometry. Accordingly, IT is produced in and by several material-discursive practices.

Furthermore, the analysis above also shows how IT (re)produces boundaries in line with the practices that enact IT. For instance, both the old driving simulator and the new test reproduced the brain as lateralized. In this sense, IT is both *produced* and *productive* – formed by material-discursive practices but also an apparatus that produces boundaries. This also means that IT is not a passive representation of social structures, but produced by and productive of them. This becomes especially salient in the agential realist analysis where it is illustrated how the *material configurations* of the IT designs produce different matters and meanings depending on the specific configuration. In this sense, IT is specific material configurations that are part of defining matter and meaning. IT enacts boundaries, making subjects and objects determinate and defined both in terms of matter and meaning, through its specific physical arrangement. In this sense, IT is part of producing the world, making IT agential.

This view of IT entails that IT is not simply inscribed with or a carrier of ‘intangible social structures’ but instead embodies these – is produced and productive in terms of matter and meaning – through specific material configurations. That IT reproduces boundaries entails that stability is produced in terms of enacted subjects, objects and meanings. This means that stability or inertia is not merely socially constructed but rather materially manifested. Accordingly, what is possible to design is not only constrained by social structures but by the materiality of IT, the material-discursive practices that enact IT and what boundaries IT helps produce. In this sense, stability or inertia is continuously produced through ongoing material-discursive practices. A key point here is that the materiality of IT produces boundaries and, thus, are part of enacting the world in a specific way. That is, the material configuration of IT matters and is not a passive feature which is merely inscribed with meaning by humans. This agential realist understanding of IT sheds light on why some changes to the design of an IT artifact are possible and others not. This is elaborated in the next section.

5.8.1. Incremental IT design – designing within material-discursive practices

The analysis above showed that it was often difficult or impossible to design configurations that was not in line with existing material-discursive practices. Instead, the design configurations had to enact subjects and meanings as desired, i.e. as they had been enacted before. Above, I referred to this as *designing within material-discursive practices*. This can be compared to previous research about innovation and design where structures – such as paradigms, regimes, frames, discourses or design spaces – limit what can be designed. That is, the design is developed in a specific frame (Norman & Verganti, 2014) or follows a specific path or technological trajectory within a paradigm (Dosi, 1982; Garud et al., 2010). The knowledge and assumptions embedded in these structures both enable and constrain what can be designed which can lead to design fixation or “paradigm-induced blindness” (Crilly, 2015, p. 57). To design within a regime – or within material-discursive practices – results in incremental innovation, i.e. continuous, cumulative and marginal improvements of existing solutions (Fagerberg, 2005). The design in the empirical case can be considered an incremental design in this sense – the new test was designed to produce boundaries that aligned with existing material-discursive practices. It was similar to the old driving simulator in many respects and enacted similar subjects and meanings. In this sense, it was an improvement of the existing driving simulator and helped the clinic to ‘do better what they already do’ (Norman & Verganti, 2014). At the same time, in the context of primary healthcare, in which the test was to be used, the new test could be considered more radically new since they had not used such a test before. Accordingly, what is considered incremental or radical innovations is dependent on context and social interpretations and agreements, as argued by Csikszentmihalyi (2014).

The agential realist analysis showed that the new design was similar to the old driving simulator in many ways. However, it was also illustrated that some design features were changed in the new test. These new designs were possible as long as they enacted subjects and meanings in line with existing material-discursive practices. That is, the boundaries were not redefined but subjects and meanings were maintained. In this sense, although there were incremental changes to the new design, it contributed to producing stability and reproducing the world in a specific way. Hence, to design within material-discursive practices is to (re)produce stability – (re)produce material-discursive practices. That is, the design of an IT artifact may change as long as it enacts boundaries in line with existing material-discursive practices. This leads to incremental changes to the design. Accordingly, from an agential realist view, incremental IT design means to design material configurations that are in line with existing material-discursive practices – to (re)produce similar boundaries to what have been enacted before.

A contributing factor to the incremental design in the empirical case was that the design had to align with *many different* material-discursive practices and enact *several* subjects and meanings, where each boundary required a specific configuration. These practices are agential since they have the power to determine what and how boundaries can be enacted.

That is, they define what differences can be produced and through which material configurations (Barad, 2007). The practices imposed different possibilities and impossibilities on the design. Put differently, these practices defined the design space – the possibilities and constraints that determine what can be designed (van Amstel et al., 2016). In this sense, the many material-discursive practices which the IT design had to align with made a rather narrow design space, which contributed to the incremental design. For instance, there were suggestions that could have been considered more innovative, such as the VR headset. This design aligned with some of the material-discursive practices (such as enactment of the brain) but did not align with others (e.g. person-centered healthcare practices). Similarly, the test results could have been pedagogically designed with three colors to help patients understand the results (i.e. a design that was in line with the material-discursive practices of person-centered healthcare). However, the test also had to enact the able health professional and this report design would diminish the health professional's agency to determine between fit and unfit drivers. Thus, it would not be in line with the material-discursive practices which defined what it means to be a health professional. Accordingly, as IT is produced by several material-discursive practices, it also has to enact boundaries that are in line with several practices. This creates a narrow design space, which explains why it is difficult to create innovative designs. That is, it is difficult to change the material configuration of a design and still (re)produce all of the different boundaries in line with the many material-discursive practices.

5.8.2. Radical IT design – deviating from material-discursive practices

If incremental design is to design within material-discursive practices, radical design entails to break with or deviate from these. Earlier research about radical innovation denote this as discontinuous changes that break with the past and with traditions, thus, being disruptive and/or competence destroying (Dahlin & Behrens, 2005; Norman & Verganti, 2014). The analysis above illustrated that more novel technologies (such as the VR headset and tablet) were impossible since they did not enact the subjects and meanings as desired, i.e. they deviated from and broke with existing material-discursive practices. Thus, these designs would have redefined the subjects and meanings – altering the material-discursive practices. In this sense, radical innovations entail that boundaries are enacted differently from existing material-discursive practices resulting in new subjects and meanings. Accordingly, radically innovative IT design is material configurations that produce new boundaries than what have been enacted before.

For instance, even small and seemingly insignificant or negligible changes to the material configurations of the IT design can be impossible because they are disruptive, i.e. they do not enact boundaries that are in line with existing material-discursive practices. The change in the design can alter the enactments of matter and meanings, and also shift agencies. The example from the empirical case where it was suggested that the test report should be visualized with red, yellow and green light illustrates this point well. This rather small and undramatic detail could have had major effects in the enactment of the health professional. This would have shifted the agency to determine who is unfit to drive or not from the

health professional to the IT artifact, rendering the health professional more passive and with less power to make a difference. That is, the health professional would have been produced as a subject whose task is to only start the test rather than as someone who assesses patients. Accordingly, this design would have been competence destroying and disruptive.

This example also illustrates how agency and boundaries are determined and defined in *material configurations* – these are not merely ‘social’ or intangible issues. The enactment of the health professional comes into being with the specific material configurations of the test. This view of IT as produced and productive helps to explain why even small changes to a design can have major implications. It is not necessarily the magnitude of the change but *what the material configuration (design) enacts* that makes a difference for if the change is possible or not. In this sense, the difficulty to design innovative IT is not only ‘in our heads’ but in the material configurations of IT and other material-discursive practices. It is difficult to change the material configuration of an IT artifact since this entails that boundaries may change which may disrupt the stability of material-discursive practices.

In summary, from an agential realist view, radical IT design means to design material configurations that break with and disrupt existing material-discursive practices – to produce boundaries that are different from what have been enacted before. These enactments are part of redefining the practices.

Difficulties to question, challenge and redefine practices

As the empirical material and analysis above show, it was not possible to radically change the subjects and meanings. This points to the difficulties to break with existing material-discursive practices and helps explain why radical innovation is rare (Sandberg & Aarikka-Stenroos, 2014). But why is it difficult to deviate from existing practices and produce different subjects, objects and meanings? One answer to these questions is that material-discursive practices are productive of a specific reality which is hard to question. It is difficult to challenge medical and mathematical practices and boundaries without coming across as a lunatic. This is because material-discursive practices are agential. They have the power to determine and define what counts as *meaningful enactments* (Barad, 2007), and these enactments have consequences for what can come into being. For instance, the analysis above illustrated that the design had to align with many different material-discursive practices. However, not all material-discursive practices mattered equally. Some practices had more agency than others and, thus, ‘trumped’ the other practices. That is, some enactments and boundaries were not possible to renegotiate or redefine. For example, the enactment of the lateralized brain was a boundary that was not open to change but instead constituted a constraint in the design – the new test had to enact the brain in line with this material-discursive practice or it would break with medical knowledge – it would not be considered legitimate. Some configurations have more agency than others and, thus, have the power to delineate what is possible and impossible to design.

Accordingly, designing IT that redefines medical boundaries is a major challenge, whereas challenging other boundaries may not be quite as difficult if these are not as ‘firm’ as medical enactments. However, it should be pointed out that even medical boundaries which we tend to see as givens can be redefined. The example about the ‘discovery’ of lymphatic vessels in the brain illustrates how even taken-for-granted boundaries can be altered when new apparatuses are used. However, not any new enactment of the brain will do. That this new knowledge of the brain gained legitimacy can be explained by the specific configurations in which it comes into being, e.g. by using accepted research practices and getting the research published in a highly reputable scientific journal. Had the same statement been uttered by a layman on the street, it would not have been taken seriously. That is, boundaries that break with existing material-discursive practices have to gain legitimacy to be accepted as a meaningful enactment. (How new boundaries gain legitimacy is an interesting question that will not be elaborated further here.)

The take-away message here is that impossible designs are constrained by material-discursive practices since the latter are agential – they make a difference for what boundaries can be enacted. This helps explain why it is difficult to design innovative IT – what can come into being is constrained by agential material-discursive practices. A practical consequence of this, suggested by Bjørn and Østerlund (2014), is to explore what boundaries are more open to renegotiation and reconfiguration and, thus, open up the design space, rather than to challenge boundaries that are more ‘fixed’. However, what boundaries should be questioned or not depends on the design situation and what the designer aims to do with the design. Challenging assumptions and the taken-for-granted may open up for more radical changes in meaning (Verganti & Öberg, 2013), such as in the example of the *Robocoaster* or the lymphatic vessels in the brain. This can then be denoted as meaning-driven innovation where meanings are radically changed (Verganti & Öberg, 2013).

Accordingly, to design radically innovative IT is difficult when there are ‘strong’ agential material-discursive practices which are not easily questioned and renegotiated (such as medical and mathematical practices). This instead leads to that IT is designed in line with these material-discursive practices, reproduce boundaries and, thus, leads to incremental innovation. As healthcare is a context with strong, agential material-discursive practices, this helps to explain why it is difficult to design innovative IT in this type of context.

5.8.3. The role of users in innovative IT design

Prior research on user involvement in design processes emphasize that users are immersed in their sociocultural regimes which makes them reproduce existing assumptions and meanings – leading to incremental innovation (Menguc et al., 2014; Norman & Verganti, 2014; Verganti, 2008). From an agential realist perspective, users are not merely ‘immersed’ in these regimes or practices but *become with them*. For instance, the health professional comes into being in intra-action with the old driving simulator (and other apparatuses used in her work, including medical practices etc.). It is through these intra-actions that the health

professional 'gains' her agency and legitimacy to assess and determine who is unfit to drive or not. Accordingly, to involve users in design processes entails not only to include individuals, but to 'invite' the material-discursive practices that produce these individuals. This has its advantages and disadvantages.

For instance, by involving users such as the health professionals from the clinic, it is easier to design an IT artifact that is tailored to the context in which the artifact is to be used. The users' knowledge and entanglement with material-discursive practices help design artifacts that enact boundaries that align with these practices. Hence, by involving users, the IT design can help create stability and continuity and potentially make implementation easier since the new artifact does not disrupt subjects, objects and meanings – e.g. the health professionals do not have to change their identities or work practices. In this sense, user involvement leads to incremental changes and less disruption. Furthermore, by involving users, the usability of the artifact may be improved (Norman & Verganti, 2014; Thakur et al., 2012). For instance, by involving the clinic, the participants in the empirical case avoided designs that would have enacted undesired boundaries which could have caused problems and made the test less usable and useful (Crilly, 2015; Thakur et al., 2012; Youmans & Arciszewski, 2014), or even lead to user resistance (Norman & Verganti, 2014), e.g. if the health professionals' agency was diminished. Such a design would have been costly and it would have taken a lot of resources to correct these design 'mistakes'. Accordingly, user involvement in IT design is advantageous in these situations.

However, if the aim is to design more radically innovative IT, involving users may be a disadvantage. Previous research indicate that expertise and domain knowledge can lead to design fixation which may inhibit new ideas and designs (Crilly, 2015; Crilly & Cardoso, 2017; Jansson & Smith, 1991; Youmans & Arciszewski, 2014). As users are becoming with specific material-discursive practices, they see and understand the world in a specific way. They may become fixated on how the problem should be solved and what boundaries the design should enact. These boundaries are then reproduced in the design by aligning the design with the material-discursive practices. Accordingly, making designs that differ from the material-discursive practices is difficult for a user who is entangled and coming into being with the very same practices. That is, users may want to contribute to innovative design and change, but may have difficulties doing so due to their entanglements with existing material-discursive practices. This was especially difficult in the empirical case where the clinic expected the new test to enact boundaries that aligned with existing material-discursive practices. This may also be extra challenging in contexts which are highly regulated and with long histories of enacting the world in a specific way, such as medicine and healthcare.

Another disadvantage of user involvement or working closely with users is that designers may become 'immersed' in the sociocultural regimes of the users (Norman & Verganti, 2014). By learning about users' assumptions, worldviews and needs, the designer becomes entangled with the practices producing these boundaries. For instance, in the empirical case, the students first did not understand why the screen width was important. But by learning

from the clinic, they started to understand that this specific configuration was necessary to measure (enact) the brain as lateralized. In this sense, they became entangled with the material-discursive practices (material configurations) that enacted the matter and meaning of the brain. As stated above, becoming entangled with the material-discursive practices of users (i.e. becoming ‘immersed’ in their sociocultural regimes) enables a better understanding of the users’ perspectives and how to design an IT artifact that suits these practices, but it may inhibit enactments of different and new boundaries – preventing radically innovative IT designs.

Design processes without user involvement can lead to more radically innovative IT that enact different subjects, objects and meanings. These new boundaries may entail that e.g. an organization adopting the innovation has to adjust in many ways to the new design. Accordingly, user involvement entails that the design of IT is mainly adjusted to fit the organization and associated material-discursive practices, whereas absence of user involvement may lead to that the users and organization have to adjust more to the new design and boundaries.

5.8.4. Aiming for radically innovative IT designs

The prior sections have focused on why it is difficult to design innovative IT from an agential realist point of view. This analysis has implications for how the challenges to design innovative IT can be met. To see the IT artifact and IT design as entangled rather than as separate entities entails that when designing IT, we have to take into account the subjects, objects and meanings that the artifact is part of producing. Here, we may change our gaze from a narrow focus on specifying the components of the IT artifact (Ralph & Wand, 2009) to looking at what subjects, objects and meanings we want the artifact to help enact. That is, we are not only designing IT, but *the world* in a broad sense. That is, the design definition as suggested by Ralph and Wand (2009) can be extended to encompass not a narrow design object such as a self-standing IT artifact but a wider notion of IT as entangled. That is, IT design is about specifying IT and entangled boundaries.

As stated above, the IT design in the empirical case had to align with several material-discursive practices which resulted in a rather narrow design space, which in turn contributed to the incremental design. However, if existing boundaries are questioned and challenged by imagining different boundaries, this may open up the design space, enabling more radical innovations. That is, by imagining different subjects, objects and meanings, the artifact may not have to align with existing material-discursive practices producing these boundaries but can contribute to redefining them somewhat. Accordingly, to facilitate for more radical IT design, (some) boundaries enacted by the artifact have to deviate from existing material-discursive practices. Hence, to design innovative IT, we may have to focus more on changing subjects, objects and meanings rather than focusing on IT as a separate and independent object – to explore what boundaries are more open to renegotiation and reconfiguration, as suggested by Bjørn and Østerlund (2014).

However, to question and challenge existing material-discursive practices and yet gain legitimacy is not easy, as pointed out above. It is especially difficult when involving users. Technology-push innovation approaches are considered more appropriate for designing radical innovation. Here, IT is developed prior to identifying user needs (Norman & Verganti, 2014). That is, IT is designed first and finding a need for the new technology is a later process. This makes technology potentially more disruptive (Norman & Verganti, 2014) since it is not tailored to and formed by existing material-discursive practices of the context of application as in user-centered design. Accordingly, by not involving users too early in a design process, designers may prevent becoming entangled with the material-discursive practices of the users. That is, this technology-push approach is potentially more radical and disruptive due to that designers are not aware of what boundaries previous artifacts have enacted and how new IT should fit into existing material-discursive practices. Or put differently, by developing IT without focusing on how it should fulfill certain needs or fit a specific context or user, the design space may be less constrained which can open up for more radical innovations.

At the same time, designers are immersed in their own paradigms and assumptions which they may not be aware of, even if they often try to reframe the design situation to break potential design fixations (Crilly, 2015; Dorst, 2010, 2011). That is, they are entangled with material-discursive practices that are difficult to question or deviate from. Here, involvement of other people may be an advantage since involving different perspectives may bring light to assumptions which the different groups take for granted (Verganti & Öberg, 2013). To combine different perspectives to help us think 'outside the box' is not a new idea in the area of creativity and innovation. However, from an agential realist perspective, it is not so much about the specific individuals that are invited to a design process but rather which material-discursive practices that are involved. Accordingly, drawing on the assumption that diversity can result in new combinations leading to innovation (Fagerberg, 2005; R. Jones, 2014; Schumpeter, 1934), it is here suggested that a diverse set of material-discursive practices are to be involved to enable this. Accordingly, to involve marginal actors and perspectives (Jeppesen & Lakhani, 2010; Provost & Jarvenpaa, 2014) can be a viable innovation strategy in the sense that people (or practices) which are peripheral to the dominant material-discursive practices can help to notice and question underlying assumptions since they apply other frames to make sense of things (Verganti & Öberg, 2013). People who are becoming with different material-discursive practices see and understand the world in different ways. By collaborating and combining these different practices, new configurations and understandings can come into being, making it easier to deviate from the dominant practices or enabling participant to make conscious choices of what assumptions, agencies and practices to reproduce or not. This could also enable the participants to become aware of what agencies and power relations IT is part of producing. However, this type of collaboration between material-discursive practices also poses many challenges, not least in terms of cooperation, agency and power, and is a topic for further studies.

Another way to enable more radically innovative IT designs is to explore uncertainties. Innovation is an inherently uncertain and risky endeavor (Fagerberg, 2005). At the same time, this uncertainty entails a window for designing something radically new (Geels, 2004). That is, to explore uncertainties entails an opportunity to define material-discursive practices since there are no existing practices making uncertain boundaries determinate. In this sense, uncertainties are opportunities to deviate from and redefine material-discursive practices. To question, challenge and explore other boundaries when designing innovative IT, as suggested above, entails to explore uncertainties. However, this entails risk as it is uncertain what new designs may result in (Crilly & Cardoso, 2017), making it especially difficult in risk averse contexts such as the public sector and healthcare (Albury, 2005) since it may affect citizens' and patients' lives and well-being (Sanandaji, 2012). In the empirical case, the uncertainty was mainly managed as a risk rather than an opportunity. The participants preferred to design in line with medical material-discursive practices and to evaluate the design with generally accepted methods, to gain legitimacy. Accordingly, risk aversion and avoidance of uncertainty contribute to incremental designs (Crilly, 2015; Youmans & Arciszewski, 2014) and are barriers to more radical designs.

As mentioned above, IT design is about designing the world – IT artifacts, subjects, objects, meanings and other boundaries. Here, ethics and values are salient – what kind of world do we want to be part of enacting? Design is ideological and affected by values and worldviews (Dunne & Raby, 2001). In our design practices, we can either reinforce the status quo and conform to existing material-discursive practices or challenge these by more disruptive and critical design (Dunne & Raby, 2001). Hence, when designing IT, we have to ask ourselves what material-discursive practices and boundaries we wish to reproduce and maintain stable and when it is appropriate to question and challenge practices and boundaries. When stability is preferred, studying prior artifacts and involving users may be a suitable choice since they know what material-discursive practices the design has to align with. On the other hand, are we looking to disrupt practices, other design strategies may be needed. In this sense, innovation and design are not inherently good or incontestably valuable (Godin, 2015; Ralph & Wand, 2009). Instead, we have to design in a way that produces the world we want to live in – whether it entails innovation or not. Accordingly, there is reason to repeat Walsham's (2012) question: Are we making a better world with IT?

5.9. Summary of Part III

The aim of Part III has been to discuss the agential realist analysis of the empirical material in light of prior research about design and innovation. Here, it was highlighted that IT is produced in and by many agential material-discursive practices and productive of boundaries. Incremental design was described as designing within or in line with existing material-discursive practices whereas radical design entails to break with or deviate from existing practices. It was discussed how user involvement leads to incremental designs, whereas technology-push innovation approaches, to question and challenge assumptions, and collaboration between various material-discursive practices were mentioned as potential

strategies to achieving radical designs. IT design was also described in agential realist terms where the scope of designs was widened from the IT artifact to IT and entangled boundaries.

Summary: IT is produced by and productive of many agential material-discursive practices. This makes incremental design – to design within material-discursive practices – less difficult than radical design since the latter has to deviate from existing practices.

In this chapter, the empirical case has been analyzed and discussed using agential realism as a theoretical lens to understand why it was difficult to design innovative IT. The tests have been studied as boundary-making practices and the impossible, possible and uncertain designs have been explored and discussed. These analyses have also been compared to historical retrospectives that have highlighted how boundaries are enacted differently by different material-discursive practices. The results of the agential realist analysis has also been related to previous research about IT design and innovation. The next chapter presents the conclusions which can be drawn from the insights provided by the analysis and discussion in this chapter.

6. Conclusions and future research

In this chapter, the research question is addressed and the conclusions, knowledge contributions and implications are presented and discussed. The quality of the thesis is also examined, followed by suggestions for future research.

6.1. Introduction

In this thesis, it has been stated that it is difficult to design innovative IT despite the rapid technological development and strong innovation trend in society today. At the same time, IT innovations are pointed out as crucial to meet the societal challenges we are facing, not least in the public sector, including a growing and older population, increasing demands and higher expectations from citizens and reduced tax revenues. This calls for us to better understand why it is difficult to design innovative IT. Previous research on this topic has mainly focused on human and social aspects, whereas the role of technology has been left out. In this thesis, it is suggested that a sociomaterial theory, such as agential realism, can help shed light on the role of IT in innovative IT design while also acknowledging social aspects. Thus, the overarching aim of this thesis is to apply agential realism on an empirical case in order to explore and explain why it is difficult to design innovative IT. The following research question is addressed:

Why is it difficult to design innovative IT?

To answer this research question, a qualitative case study was conducted in a healthcare organization. The healthcare sector faces both a need for IT innovations but also many barriers to designing innovative IT, e.g. conservative and bureaucratic structures, laws and regulations, knowledge intensive practices and strong professions. Yet, there are also many examples of innovation in healthcare, demonstrating that innovation is possible in this context. Hence, the healthcare sector was considered a suitable context in which to study the research question. In the agential realist analysis, IT has been viewed as entangled with, and as making differences in, the world. The analysis focused on what boundaries IT produced and how these boundaries were consequential for what was possible and impossible to design.

Below, the conclusions of the thesis are presented. These are made in Barad's (2007) vocabulary since her terminology is needed to avoid resorting to dualistic language that divides the world into separate things. However, to avoid a much too abstract account, practical implications are suggested and discussed in relation to the conceptual explanations. This is followed by an account of the knowledge contributions which also are discussed in terms of research implications. After that, an examination of the thesis' quality is provided and, finally, suggestions for future research are made.

6.2. Conclusions and implications for practice

This study has shown how IT makes a difference in the world. It has been illustrated that IT is produced, i.e. coming into being, becoming distinct and gaining its meaning in entanglement with several material-discursive practices. Furthermore, IT has also been illustrated as productive, i.e. that IT produces boundaries and, thus, enacts the world in specific ways. Here, the materiality of IT is highlighted. In agential realist terms, the physical arrangement of IT produces boundaries. That is, the specific material configurations of IT are part of producing and defining matter and meaning. For instance, even small changes to the IT design can result in that boundaries are enacted differently, e.g. that subjects, objects and meanings are changed. In less theoretical terms, this means that IT is part of making the world distinct as we know it.

This understanding of IT has implications for practitioners in IT design. To see IT as entangled and productive entails that people engaging in design need to broaden their scope from specifying the components of the IT artifact as a separate entity, to looking at what subjects, objects and meanings the design enacts. For instance, this can include that designers study how changes in the IT design draw different lines or affect different users' agency. That is, designers should pose the questions: What differences do the IT design make in the world? For what and for whom? Accordingly, there are important ethical implications in this view of IT design. IT designers do not only design an IT artifact but contribute to producing people and things in specific ways. This entails that IT designers also should pose the questions: Do our IT designs produce a world we want to be a part of? What meanings do we want to reproduce and when is it desirable and appropriate to question and challenge the state of things? This also raises the questions of who gets to influence the IT design, when innovation is appropriate and what kind of world IT should reproduce or not.

This understanding of IT as produced and productive helps us understand why it is difficult to design innovative IT. The agential realist analysis in this thesis shows that it was possible to design IT that made distinctions which aligned with prevailing understandings. That is, it was possible to design IT that produced boundaries which aligned with existing material-discursive practices and, thus, enacted subjects and meanings as desired. However, IT designs that produced boundaries which deviated from or risked to deviate from prevailing understandings (i.e. existing material-discursive practices) were impossible or uncertain. This is explained by that material-discursive practices are agential and determine what counts as meaningful enactments and what can come into being. That is, these practices, which perform specific enactments of the world, have the power to define what designs are desired and legitimate, i.e. what IT designs produce meaningful boundaries. For instance, potentially innovative IT designs may not be seen as legitimate as they deviate too much from the material-discursive practices and, thus, are considered impossible. Accordingly, *it is difficult to design radically innovative IT when there are strong, agential material-discursive practices which are not easily questioned or renegotiated*. Instead, the IT design has to conform to the material-

discursive practices to gain legitimacy. This leads to incremental IT designs that reproduce boundaries in line with these practices. Accordingly, material-discursive practices constrain what is possible to design.

Adding to this difficulty is that IT may produce several, entangled boundaries and, thus, has to align with several different material-discursive practices to gain legitimacy. This further limits the possibilities for innovative IT design. When making changes to the material configuration (i.e. the design) of an IT artifact, the new design may enact some boundaries as desired whereas other boundaries may break with some material-discursive practices in undesirable ways. That is, the materiality of IT has to align with many different practices which narrows down the design space. Accordingly, that there are many different agential material-discursive practices contribute to the difficulties of designing innovative IT, i.e. there are several practices exerting power in defining if the design is enacting meaningful boundaries or not. This study has illustrated healthcare as a context with several agential material-discursive practices that limit what is possible to design. This contributes to our understanding of why it is difficult to design innovative IT in this type of context.

Innovative IT design means to design material configurations that produce boundaries that are different from what have been enacted before and, thus, deviate from existing material-discursive practices. However, it is difficult to deviate from these since material-discursive practices are agential and define what boundaries are meaningful and legitimate – not any enactment is acceptable. Accordingly, *it is difficult to design innovative IT since innovative IT design has to both enact boundaries that deviate from several agential material-discursive practices and also gain legitimacy.*

This conceptual explanation suggests a couple of practical implications for designers aiming for innovative IT. As indicated above, designers should not have a narrow focus on the IT artifact but rather imagine how meanings and subjects may be changed through IT design. For instance, what could it mean to be a health professional or a patient and how can IT contribute to enacting these subjects? In this sense, innovative IT design is about questioning existing boundaries and imagining other boundaries. By questioning and challenging existing boundaries, the design space can be opened up, enabling potential other subjects and meanings and, thus, also innovative IT design. This entails that designers have to explore uncertainties since innovative IT design entails to deviate from existing understandings of people and things.

Furthermore, involvement of users become an important aspect here, both in terms of ethical considerations but also when aiming to design innovative IT. From an agential realist perspective, people are understood as becoming with different material-discursive practices which entails that they see and understand the world in different ways. This can be disadvantageous but also used as an advantage when designing innovative IT. Previous research point to that user involvement and close collaboration with users is advantageous as it helps designers to better understand the users' needs and perspectives, making it easier for designers to adjust the design to fit the specific context. By involving and collaborating with users, the IT design can be aligned with existing material-discursive practices. Hence,

this leads to incremental IT designs. However, when aiming for radically innovative IT designs, user involvement can be disadvantageous since users' entanglement with existing material-discursive practices of their specific context makes it difficult for them to question or imagine different boundaries. In these instances, the line of reasoning presented in this thesis suggests that IT designers aiming for radical IT designs should not start their design process from user needs but rather involve persons who become with other material-discursive practices than that of the main users. For instance, this can include peripheral perspectives and to combine various different practices which can shed light on taken-for-granted boundaries and help to deviate from existing and dominant understandings of what boundaries IT should produce.

6.3. Knowledge contributions and implications for research

In the introduction of this thesis, several prospective knowledge contributions were identified. These are discussed in this section. First, by applying an agential realist perspective, the thesis sought to present a new perspective and understanding of the difficulties of designing innovative IT, which differed from earlier explanations found in previous research. The thesis also makes such a knowledge contribution by providing an understanding of these difficulties with emphasis on the role of IT, materiality, entanglements and agency. These conceptual explanations differ from earlier knowledge which focus on human and social aspects. The explanations provided in this thesis align with much of the previous research but adds an understanding of why it is difficult to break with structures and change the design of an IT artifact. Here, the role of materiality as a constituting agency of what is possible and impossible adds to our understanding of inertia in design. That is, what is possible to design is not only constrained by social structures but by the materiality of IT, what boundaries IT helps produce and the material-discursive practices that enact IT. This knowledge contribution is relevant for researchers and practitioners in different fields who are interested in understanding why it is difficult to design innovative IT. It can also inform researchers and practitioners interested in the broader topics of change and inertia.

This new understanding also makes a contribution to conceptualizing the IT artifact. That is, the thesis provides examples of how IT can be understood and theorized as produced, productive, emergent, agential and entangled. This contribution can be useful for researchers in the IS field in general and the sociomaterial research stream in particular. For instance, this reconceptualization of IT have implications for how IS researchers may approach IT and IS phenomena in future research. Here, IT is viewed as entangled rather than as separate and determinate, prompting researchers to study material-discursive practices and the becoming of boundaries rather than predefined entities. This view can inform IS research in which change and inertia are addressed. Also other IS topics may benefit from this reconceptualization as it provides a theoretical lens that can shed new light on areas which are already extensively researched.

The thesis also makes an empirical contribution to the sociomaterial research stream, in which empirical accounts that fully apply sociomaterial theories, and agential realism in particular, are scarce (M. Jones, 2014). As sociomaterial research in the IS field is in its infancy, there is also a scarcity in methodological contributions. This thesis constitutes a methodological contribution in the sense that it demonstrates how an agential realist case study can be conducted, how empirical data can be analyzed from an agential realist perspective, including genealogical analysis, and how agential realist research can be evaluated, e.g. in terms of accountability and the role of the researcher. By applying agential realism in the IS field, the thesis makes both empirical and methodological contributions that, hopefully, can inform and inspire researchers who are interested in applying agential realism in future research.

These knowledge contributions can also be discussed in terms of generalizability. In Chapter 3, it was pointed out that general notions and theories can be useful when making sense of similar situations or phenomena (Maxwell, 1992). Here, it is my belief that the conceptual explanations and line of reasoning provided in this thesis about why it is difficult to design innovative IT can inform similar situations. The explanations may be especially useful in contexts similar to healthcare, e.g. highly institutionalized and knowledge intensive organizations. However, I do not consider the knowledge contributions as limited only to healthcare and similar contexts or only encompassing medical devices. This does not mean that medical devices are not different from other IT, but that the specific enactments of IT does not change the more general notion that IT is agential, produced and productive. However, it is not possible to generalize the specific configurations or enactments that are described in this study. These are ongoing, multiple and changing and cannot be transferred from one case to the next. These enactments may even be enacted differently in the existing case – as Barad (2007, p. 177) points out – boundaries “do not sit still”. This is a limitation of the research. I also acknowledge that the research question has not been brought to a close here. Other enactments and boundaries are possible when aiming to explain why it is difficult to design innovative IT, which is not to be seen as a failure to answer the research question, but a recognition of the world’s ongoing entanglements and multiplicity.

It is my opinion that new and interesting insights are provided by applying agential realism to understand and explain why it is difficult to design innovative IT. This is also a key criterion when assessing the quality of research in which theories for explaining are applied (Gregor, 2006). The theoretical lens has widened and extended my understanding of the difficulties of innovative IT design. To conclude, I believe that the thesis offers a substantial step towards increasing our understanding of why it is difficult to design innovative IT and I hope that also the reader finds the conclusions and contributions thought-provoking and fruitful.

6.4. Quality assessment

In Chapter 3, it was stated that researchers drawing on agential realist assumptions of the world should account for the apparatuses that produce the research to enable readers to

scrutinize the relevance and rigor of the research. That is, researchers and their practices are both productive of boundaries but also entangled and produced by other practices. Drawing on this line of reasoning, I acknowledge my historical, social, political and cultural entanglement and that this affects the boundaries produced in this thesis. Due to this, I have tried to make a transparent account of the research apparatuses producing the research in this thesis. This is done throughout the thesis, but especially in Chapter 3 where I discuss methodological considerations. Hopefully, these accounts help readers to assess the research and deem for themselves if they find it relevant and rigorous. I will here discuss some of the most important apparatuses in the research process; the researcher, the research question, data generations techniques and theory.

To make my role as a researcher transparent, I have tried to make clear accounts of my background, interests, assumptions and beliefs. For instance, I have described my motivations for studying innovation and also my critical position that innovation is not necessarily the answer to all our challenges. As mentioned in Chapter 3, my interests and my participant observations were important aspects in how the research question emerged. These are all apparatuses which have focused my analytical gaze to the inclusion and exclusion of different details and interpretations in the study. Furthermore, my presence during the participant observations affected the data generation to some extent although it is difficult to say exactly how. Some clear examples include that participants commented on the recording equipment from time to time. However, I do not think that my presence during the observations have affected the IT design or the courses of the projects. That is, I don't think the design would have looked much different or the projects played out differently if I had not been a part of the process. In this sense, I deem myself as a rather unimportant apparatus in that particular enactment. However, I acknowledge my accountability for my descriptions and enactments of the empirical data. For instance, the research question, theories and my foci affected my descriptions of the driving simulator. That is, these descriptions are intra-acting with these apparatuses – coming into being in entanglement with me as a researcher and the research practices. This also entails that other interpretations and boundaries could have been made depending on who the researcher is, what methods were used and questions were asked. For instance, had I had other interests, preconceptions and knowledge, different things would have been enacted in this research. I have no doubt that researchers from other fields would have paid attention to other things and, thus, enacted the case differently. Accordingly, the particular apparatuses used in this research have led to certain exclusions which have not been made intentionally.

Other exclusions have been made on purpose. That is, I have intentionally delimited my analysis to incorporate what I found to be the most salient configurations in the case. For instance, I have not highlighted electricity as an important part of the configuration even though the IT artifacts could not function without it. Neither have I emphasized that the health professionals could not work without their education or even basic needs such as food. These specific configurations could surely be included in the analysis as they are part of enacting boundaries in the case. However, I have followed Barad's (2007) advice to focus

on what I have found to be the most important apparatuses in the enactment of boundaries in the case, without drowning in details or simplifying for the sake of convenience. This has been a way to avoid Mutch's (2013, p. 34) critique that agential realist analyses result in "long lists of factors which produce particular results". That is, I have intentionally tried to limit the amount of details in my descriptions. However, as details matter in agential realist analyses, my goal has been to include enough empirical aspects to provide a meaningful account and analysis of the case. My hope is that the detailed examples also provide the reader with comprehensible illustrations to accompany the rather complex and abstract theory.

One of the most prominent apparatuses in the analysis of the case is agential realism. The theory is used as a 'sensitizing device' to understand and explain the world in new and altered ways (Gregor, 2006; Klein & Myers, 1999). As agential realism draws on a relational ontology, this has implications for enacting IT, subjects and meanings as entangled. This can be contrasted to representationalist assumptions and theories which enact these things as separate and pre-existing. Accordingly, it is important to point out the agency of the theoretical apparatus in producing the boundaries in this thesis. Another example of this is that I have tried to follow Barad's (2007) recommendation to include both discourse and materiality as inseparable to make adequate empirical accounts. This might not have been the case had I applied another theory in my analysis.

An important aspect to point out here is that apparatuses are open-ended (Barad, 2007). This entails that agential realist analyses cannot be exhaustive. It also entails that it is impossible to give a comprehensive account of all practices that contribute to this research. Instead, I have tried to provide an account – as detailed and transparent as possible – that enables readers to make their own judgements of the research presented here. Accordingly, I am aware that I cannot account for all apparatuses and, thus, that closure is impossible. My own evaluation of the thesis is that it addresses a relevant research question and that appropriate research methods and techniques have been applied to address the research question. The empirical material includes both rich contextual information and details that have allowed for several rounds of thorough analyses. These theoretical analyses are also connected back to the research question in the form of relevant and applicable knowledge contributions. The research is also communicated as transparently as possible to allow for scrutiny of both research product and process. My hope is that the reader can follow the lines of argument in the thesis and come to similar conclusions.

6.4.1. Ethical considerations

Ethical considerations are important when assessing the quality of research. Also here, I have tried to be as open and transparent as possible in terms of ethics and how I have aimed to protect participants from any harm. I have followed the ethical guidelines provided by the Swedish Research Council, including informed consent and confidentiality. When conducting fieldwork, I have always introduced myself as a PhD student conducting research, informed participants about my research interests and focus as detailed and

comprehensive as possible and never withheld any information that I thought could affect the participants' consent. I have also always asked for permission to observe meetings but most often, I have been invited by the participants themselves. Accordingly, I find that participants have been informed and aware of that they are being subject to research and given opportunities to withdraw from the study by denying me access to their meetings.

From an agential realist perspective, ethics also entails being accountable for the boundaries produced. I acknowledge my ethical accountability in enacting this research and part of the world in specific ways through my research practices. My aspiration of this research and by applying agential realism has been to open up for new configurations and understandings that encompass the complexity of the world. Hence, I hope this piece of work contributes to new understandings of IS phenomena in general and innovative IT design in particular, adding to the diversity in the IS field.

6.5. Future research

The knowledge contributions of this thesis open up for different lines of future research. For instance, now that some light has been shed on the difficulties of designing innovative IT, a next step could be to study how to support and facilitate innovative IT design. A few suggestions have been made already, including the involvement of peripheral perspectives. What other ways are there to question taken-for-granted boundaries and to deviate from existing and dominant understandings of what boundaries IT should produce? What are the pros and cons of these strategies? This also makes combination of different material-discursive practices and collaboration between subjects who become with different material-discursive practices interesting topics. What are the challenges and possibilities of such cross-border and diverse collaborations?

This line of thinking also opens up for further study of legitimacy and agency. How is legitimacy enacted in different settings? How does various material-discursive practices gain agency and what determines what practices have more agency than the next? Or put differently; why are some practices 'more' agential than others, determining what is possible or impossible? When innovations *do* occur, how do shifts in agency happen? That is, how are matter and meaning redefined and changed?

Finally, as this thesis has shown that agential realism is a fruitful theoretical lens when studying IT, this also opens up for other studies in the IS field. Here, an agential realist perspective can shed new light on typical IS topics that previously only have been studied from representationalist point of views, e.g. through positivist or interpretive research. This may entail that taken-for-granted boundaries can be scrutinized and understood in terms of their materiality, how they are enacted and consequential. This can provide additional understandings and explanations of already well-researched areas.

References

- Albury, D. (2005). Fostering Innovation in Public Services. *Public Money & Management*, 25(1), 51–56.
- Ali, M., Zhou, L., Miller, L., & Ieromonachou, P. (2016). User resistance in IT: A literature review. *International Journal of Information Management*, 36(1), 35–43.
- Alvesson, M., & Sköldbberg, K. (2017). *Reflexive Methodology: New Vistas for Qualitative Research*. London: SAGE Publications Ltd.
- Atkinson, L. (2001). Intellectual Functioning, Assessment of. In N. J. Smelser & P. B. Baltes (Eds.), *International Encyclopedia of the Social & Behavioral Sciences* (pp. 7600–7605). Oxford: Pergamon.
- Bannon, L. J., & Ehn, P. (2013). Design: Design Matters in Participatory Design. In J. Simonsen & T. Robertson (Eds.), *Routledge International Handbook of Participatory Design* (pp. 37–63). New York: Routledge.
- Barad, K. (1996). Meeting the universe halfway: Realism and social constructivism without contradiction. In L. H. Nelson & J. Nelson (Eds.), *Feminism, science, and the philosophy of science* (pp. 161–194). Dordrecht: Kluwer Academic Publishers.
- Barad, K. (1998). Getting real: Technoscientific practices and the materialization of reality. *Differences: A Journal of Feminist Cultural Studies*, 10(2), 87–128.
- Barad, K. (2003). Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter. *Signs: Journal of Women in Culture and Society*, 28(3), 801–831.
- Barad, K. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Durham: Duke University Press.
- Barad, K. (2014). Diffracting Diffraction: Cutting Together-Apart. *Parallax*, 20(3), 168–187.
- Baregheh, A., Rowley, J., & Sambrook, S. (2009). Towards a multidisciplinary definition of innovation. *Management Decision*, 47(8), 1323–1339.
- Benbasat, I., Goldstein, D. K., & Mead, M. (1987). The Case Research Strategy in Studies of Information Systems. *MIS Quarterly*, 11(3), 369–386.
- Benbasat, I., & Weber, R. (1996). Research Commentary: Rethinking “Diversity” in Information Systems Research. *Information Systems Research*, 7(4), 389–399.
- Benbasat, I., & Zmud, R. W. (2003). The Identity Crisis within the IS Discipline: Defining and Communicating the Discipline’s Core Properties. *MIS Quarterly*, 27(2), 183–194.
- Berkhout, F. (2002). Technological regimes, path dependency and the environment. *Global Environmental Change*, 12(1), 1–4.
- Bijker, W. E. (1987). The social construction of Bakelite: Toward a theory of invention. In W. E. Bijker, T. P. Hughes, & T. Pinch (Eds.), *The social construction of technological systems - New directions in the sociology and history of technology* (pp. 159–187). Cambridge: The MIT Press.
- Bjørn, P., & Østerlund, C. (2014). *Sociomaterial-Design: Bounding technologies in practice*. London: Springer.

- Bloch, C., & Bugge, M. M. (2013). Public sector innovation—From theory to measurement. *Structural Change and Economic Dynamics*, 27, 133–145.
- Borins, S. (2001). Encouraging innovation in the public sector. *Journal of Intellectual Capital*, 2(3), 310–319.
- Brandt, E., & Eriksen, M. A. (2010). From a blank slate or a full table? Kicking off innovation by exploring the well-known. In J. Halse, E. Brandt, B. Clark, & T. Binder (Eds.), *Rehearsing the Future* (pp. 74–79). Copenhagen: The Danish Design School Press.
- Brown, A. (2014). The place of ethnographic methods in information systems research. *International Journal of Multiple Research Approaches*, 8(2), 166–178.
- Brunken, R., Plass, J. L., & Leutner, D. (2003). Direct Measurement of Cognitive Load in Multimedia Learning. *Educational Psychologist*, 38(1), 53–61.
- Castiaux, A. (2007). Radical innovation in established organizations: Being a knowledge predator. *Journal of Engineering and Technology Management*, 24(1), 36–52.
- Cavaye, A. L. M. (1996). Case study research: A multi-faceted research approach for IS. *Information Systems Journal*, 6(3), 227–242.
- Cecez-Kecmanovic, D., Galliers, R. D., Henfridsson, O., Newell, S., & Vidgen, R. (2014). The Sociomateriality of Information Systems: Current Status, Future Directions. *MIS Quarterly*, 38(3), 809–830.
- Cerebral hemisphere. (2017, August 7). In *Wikipedia*. Retrieved from https://en.wikipedia.org/w/index.php?title=Cerebral_hemisphere&oldid=794295238
- Cooper, R. B. (2000). Information Technology Development Creativity: A Case Study of Attempted Radical Change. *MIS Quarterly*, 24(2), 245–276.
- Corsaro, W. A. (1982). Something Old and Something New: The Importance of Prior Ethnography in the Collection and Analysis of Audiovisual Data. *Sociological Methods & Research*, 11(2), 145–166.
- Creswell, J. W., & Miller, D. L. (2000). Determining Validity in Qualitative Inquiry. *Theory Into Practice*, 39(3), 124–130.
- Crilly, N. (2015). Fixation and creativity in concept development: The attitudes and practices of expert designers. *Design Studies*, 38, 54–91.
- Crilly, N., & Cardoso, C. (2017). Where next for research on fixation, inspiration and creativity in design? *Design Studies*, 50, 1–38.
- Cross, N. (2001). Design/science/research: developing a discipline. Presented at the Fifth Asian Design Conference: International Symposium on Design Science, Seoul, Korea: Su Jeong Dang Printing Company.
- Csikszentmihalyi, M. (2014). Society, Culture, and Person: A Systems View of Creativity. In M. Csikszentmihalyi (Ed.), *The Systems Model of Creativity: The Collected Works of Mihaly Csikszentmihalyi* (pp. 47–61). Dordrecht: Springer.
- Dahlin, K. B., & Behrens, D. M. (2005). When is an invention really radical? Defining and measuring technological radicalness. *Research Policy*, 34(5), 717–737.

- Darke, P., Shanks, G., & Broadbent, M. (1998). Successfully completing case study research: combining rigour, relevance and pragmatism. *Information Systems Journal*, 8(4), 273–289.
- De Vries, H., Bekkers, V., & Tummers, L. (2016). Innovation in the Public Sector: A Systematic Review and Future Research Agenda. *Public Administration*, 94(1), 146–166.
- Dehue, G. C. G. T. (2001). Experimentation in Psychology, History of. In N. J. Smelser & P. B. Baltes (Eds.), *International Encyclopedia of the Social & Behavioral Sciences* (pp. 5115–5120). Oxford: Pergamon.
- Díaz Andrade, A., Urquhart, C., & Arthanari, T. (2015). Seeing for Understanding: Unlocking the Potential of Visual Research in Information Systems. *Journal of the Association for Information Systems*, 16(8), 646–673.
- Dingwall, R. (1980). Ethics and Ethnography. *Sociological Review*, 28(4), 871–891.
- Dorst, K. (2010). The nature of design thinking. In *Proceedings of the 8th Design Thinking Research Symposium* (pp. 131–139). Sydney: DAB Documents.
- Dorst, K. (2011). The core of ‘design thinking’ and its application. *Design Studies*, 32(6), 521–532.
- Dorst, K., & Dijkhuis, J. (1995). Comparing paradigms for describing design activity. *Design Studies*, 16(2), 261–274.
- Dosi, G. (1982). Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. *Research Policy*, 11(3), 147–162.
- Driver. (2017, July 24). In *Wikipedia*. Retrieved from <https://en.wikipedia.org/w/index.php?title=Driver&oldid=792039048>
- Driving. (2017, September 28). In *Wikipedia*. Retrieved from <https://en.wikipedia.org/w/index.php?title=Driving&oldid=802810686>
- Dunne, A., & Raby, F. (2001). *Design Noir: The Secret Life of Electronic Objects*. Basel: Birkhäuser.
- Ekman, I., Norberg, A., & Swedberg, K. (2014). Tillämpning av personcentrering inom hälso- och sjukvård. In I. Ekman (Ed.), *Personcentrering inom hälso- och sjukvård: Från filosofi till praktik* (pp. 69–112). Stockholm: Liber.
- Esterberg, K. G. (2002). *Qualitative methods in social research*. Boston: McGraw-Hill.
- Fagan, M. H. (2004). The influence of creative style and climate on software development team creativity: An exploratory study. *The Journal of Computer Information Systems*, 44(3), 73.
- Fagerberg, J. (2005). Innovation—A Guide to the Literature. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation*. New York: Oxford University Press.
- Fichman, R. G., Dos Santos, B. L., & Zheng, Z. E. (2014). Digital Innovation as a Fundamental and Powerful Concept in the Information Systems Curriculum. *MIS Quarterly*, 38(2), 329–A15.

- Fontana, A., & Frey, J. H. (1994). Interviewing: The art of science. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research*. (pp. 361–376). Thousand Oaks: Sage Publications, Inc.
- Forty, A. (1986). *Objects of desire: Design and society since 1750*. London: Thames & Hudson.
- Frankelius, P. (2014). *Innovation i offentlig sektor: Var står vi? Vart går vi?* Stockholm: Sveriges Kommuner och Landsting (SKL).
- Frensch, P. A. (2001). Cognitive Psychology: Overview. In N. J. Smelser & P. B. Baltes (Eds.), *International Encyclopedia of the Social & Behavioral Sciences* (pp. 2147–2154). Oxford: Pergamon.
- Friedman, K. (2003). Theory construction in design research: Criteria, approaches, and methods. *Design Studies*, 24(6), 507–522.
- Fries, R. C. (1997). *Reliable design of medical devices*. New York: Marcel Dekker.
- Gallouj, F., & Zanfei, A. (2013). Innovation in Public Services: Filling a Gap in the Literature. *Structural Change and Economic Dynamics*, 27, 89–97.
- Garud, R., & Karnøe, P. (2001). *Path Dependence and Creation*. Hove: Psychology Press.
- Garud, R., Kumaraswamy, A., & Karnøe, P. (2010). Path Dependence or Path Creation? *Journal of Management Studies*, 47(4), 760–774.
- Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, 33(6), 897–920.
- Godin, B. (2015). *Innovation contested: The idea of innovation over the centuries*. New York: Routledge.
- Goldkuhl, G. (2004). Design Theories in Information Systems: A Need for Multi-Grounding. *Journal of Information Technology Theory and Application*, 6(2), 59–72.
- Goldkuhl, G. (2016). E-government design research: Towards the policy-ingrained IT artifact. *Government Information Quarterly*, 33(3), 444–452.
- Gourville, J. T. (2006). Eager sellers and stony buyers: Understanding the psychology of new product adoption. *Harvard Business Review*, 84(6), 98–106.
- Greener, I. (2002). Theorising path-dependency: How does history come to matter in organisations? *Management Decision*, 40(6), 614–619.
- Gregor, S. (2006). The Nature of Theory in Information Systems. *MIS Quarterly*, 30(3), 611–642.
- Gulliksen, J. (2006). How Do Developers Meet Users? – Attitudes and Processes in Software Development. In G. Doherty & A. Blandford (Eds.), *Interactive Systems. Design, Specification, and Verification* (pp. 1–10). Springer-Verlag Berlin Heidelberg.
- Hammer, M. (1990). Reengineering Work: Don't Automate, Obliterate. *Harvard Business Review*, July-August, 104–112.
- Hartley, J. (2005). Innovation in governance and public services: Past and present. *Public Money and Management*, 25(1), 27–34.
- Heath, C., Hindmarsh, J., & Luff, P. (2010). *Video in Qualitative Research*. Los Angeles: SAGE Publications Ltd.

- Hedman, H. (2014). Patientens - personens röst. In I. Ekman (Ed.), *Personcentrerad inom hälso- och sjukvård: Från filosofi till praktik* (pp. 7–20). Stockholm: Liber.
- Heiskanen, E., Hyvönen, K., Niva, M., Pantzar, M., Timonen, P., & Varjonen, J. (2007). User involvement in radical innovation: are consumers conservative? *European Journal of Innovation Management*, 10(4), 489–509.
- Henfridsson, O., Yoo, Y., & Svahn, F. (2009). Path creation in digital innovation: A multi-layered dialectics perspective. *Sprouts: Working Papers on Information Systems*, (9), 1–26.
- Herzlinger, R. E. (2006). Why innovation in health care is so hard. *Harvard Business Review*, 84(5), 58.
- Heskett, J. (2003). *Toothpicks and logos: Design in everyday life*. Oxford: Oxford University Press.
- Hevner, A., & Chatterjee, S. (2010). *Design Research in Information Systems*. New York: Springer Publishing.
- Information technology. (n.d.). Retrieved from [https://www.merriam-webster.com/dictionary/information technology](https://www.merriam-webster.com/dictionary/information%20technology)
- Jansson, D. G., & Smith, S. M. (1991). Design fixation. *Design Studies*, 12(1), 3–11.
- Jeppesen, L., & Lakhani, K. (2010). Marginality and problem-solving effectiveness in broadcast search. *Organization Science*, 21(5), 1016–1033.
- Jha, A. K., & Bose, I. (2016). Innovation research in information systems: A commentary on contemporary trends and issues. *Information & Management*, 53(3), 297–306.
- Jones, M. (2014). A Matter of Life and Death: Exploring Conceptualizations of Sociomateriality in the Context of Critical Care. *MIS Quarterly*, 38(3), 895-A6.
- Jones, R. (2010). Creativity and discourse. *World Englishes*, 29(4), 467–480.
- Jones, R. (2014). Introduction: Discourse and Creativity. In R. Jones (Ed.), *Discourse and Creativity* (pp. 1–13). Harlow: Pearson Education Limited.
- Jordanova, M., & Lievens, F. (24-26 November). Global Telemedicine and eHealth (A synopsis). In *Proceedings of the 3rd International Conference on E-Health and Bioengineering - EHB* (pp. 1–6). Iași, Romania.
- Jorgensen, D. L. (1989). *Participant observation: A methodology for human studies*. Newbury Park: Sage.
- Kautz, K., & Jensen, T. B. (2012). Sociomateriality: More than jargon monoxide? Questions from the jester to the sovereigns. *European Conference on Information Systems (ECIS) 2012 Proceedings*, (Paper 54).
- Kautz, K., & Jensen, T. B. (2013). Sociomateriality at the royal court of IS: A jester's monologue. *Information and Organization*, 23(1), 15–27.
- Klein, H. K., & Myers, M. D. (1999). A Set of Principles for Conducting and Evaluating Interpretive Field Studies in Information Systems. *MIS Quarterly*, 23(1), 67–93.
- Krippendorff, K. (1989). On the Essential Contexts of Artifacts or on the Proposition That "Design Is Making Sense (Of Things)." *Design Issues*, 5(2), 9–39.
- Kristensson Ugglå, B. (2014). Personfilosofi - filosofiska utgångspunkter för personcentrerad inom hälso- och sjukvård. In I. Ekman (Ed.), *Personcentrerad inom hälso- och sjukvård: Från filosofi till praktik* (pp. 21–96). Stockholm: Liber.

- Kuntz, A. M., & Presnall, M. M. (2012). Wandering the Tactical From Interview to Intraview. *Qualitative Inquiry*, 18(9), 732–744.
- Lateralization of brain function. (2017, August 25). In *Wikipedia*. Retrieved from https://en.wikipedia.org/w/index.php?title=Lateralization_of_brain_function&oldid=797172865
- Lee, A. S. (2001). Editor's comments. *MIS Quarterly*, 25(1), iii–vii.
- Lee, A. S., & Baskerville, R. L. (2003). Generalizing Generalizability in Information Systems Research. *Information Systems Research*, 14(3), 221–243.
- Leonardi, P. M. (2013). Theoretical foundations for the study of sociomateriality. *Information & Organization*, 23(2), 59–76.
- Lettl, C. (2007). User involvement competence for radical innovation. *Journal of Engineering and Technology Management*, 24(1–2), 53–75.
- Li, Y., Wang, J., Li, X., & Zhao, W. (2006). Design creativity in product innovation. *The International Journal of Advanced Manufacturing Technology*, 33(3–4), 213–222.
- Lientz, B. P., & Rea, K. P. (2004). *Breakthrough IT Change Management: How to Get Enduring Change Results*. Oxford: Elsevier Butterworth-Heinemann.
- Louveau, A., Smirnov, I., Keyes, T. J., Eccles, J. D., Rouhani, S. J., Peske, J. D., ... Kipnis, J. (2015). Structural and functional features of central nervous system lymphatic vessels. *Nature*, 523(7560), 337–341.
- Löwgren, J., & Stolterman, E. (2004). *Thoughtful interaction design: A design perspective on information technology*. Cambridge: MIT Press.
- Lubanski, N., Klæsøe, B., Johns, L., & Forslund, D. (2015). *Välfärdsinnovation*. Lund: Studentlitteratur.
- Lyytinen, K., & Rose, G. M. (2003). Disruptive information system innovation: the case of internet computing. *Information Systems Journal*, 13(4), 301–330.
- March, S. T., & Storey, V. C. (2008). Design science in the information systems discipline: An introduction to the special issue on design science research. *MIS Quarterly*, 32(4), 725–730.
- Maxwell, J. (1992). Understanding and validity in qualitative research. *Harvard Educational Review*, 62(3), 279–301.
- Mazzei, L. A. (2013). A voice without organs: Interviewing in posthumanist research. *International Journal of Qualitative Studies in Education*, 26(6), 732–740.
- Menguc, B., Auh, S., & Yannopoulos, P. (2014). Customer and Supplier Involvement in Design: The Moderating Role of Incremental and Radical Innovation Capability. *Journal of Product Innovation Management*, 31(2), 313–328.
- Meningeal lymphatic vessels. (2017, August 10). In *Wikipedia*. Retrieved from https://en.wikipedia.org/w/index.php?title=Meningeal_lymphatic_vessels&oldid=794864317
- Mental chronometry. (2017, August 14). In *Wikipedia*. Retrieved from https://en.wikipedia.org/w/index.php?title=Mental_chronometry&oldid=795430376

- Meyer, U., & Schubert, C. (2007). Integrating path dependency and path creation in a general understanding of path constitution. The role of agency and institutions in the stabilisation of technological innovations. *Science, Technology & Innovation Studies*, 3(1), 23–44.
- Michell, J. (2001). Measurement Theory: History and Philosophy. In N. J. Smelser & P. B. Baltes (Eds.), *International Encyclopedia of the Social & Behavioral Sciences* (pp. 9451–9454). Oxford: Pergamon.
- Mutch, A. (2013). Sociomateriality — Taking the wrong turning? *Information and Organization*, 23(1), 28–40.
- Myers, M. D. (1999). Investigating information systems with ethnographic research. *Communications of the AIS*, 2(23), 1–20.
- Myers, M. D. (2013). *Qualitative Research in Business and Management* (Second Edition). Thousand Oaks: SAGE Publications Ltd.
- Myers, M. D., & Newman, M. (2007). The qualitative interview in IS research: Examining the craft. *Information and Organization*, 17(1), 2–26.
- Nandhakumar, J., & Jones, M. (1997). Too close for comfort? Distance and engagement in interpretive information systems research. *Information Systems Journal*, 7(2), 109–131.
- Nordstrom, S. N. (2015). Not So Innocent Anymore: Making Recording Devices Matter in Qualitative Interviews. *Qualitative Inquiry*, 21(4), 388–401.
- Norman, D. A., & Verganti, R. (2014). Incremental and Radical Innovation: Design Research vs. Technology and Meaning Change. *Design Issues*, 30(1), 78–96.
- Orlikowski, W. J. (2007). Sociomaterial Practices: Exploring Technology at Work. *Organization Studies*, 28(9), 1435–1448.
- Orlikowski, W. J., & Baroudi, J. J. (1991). Studying information technology in organizations: Research approaches and assumptions. *Information Systems Research*, 2(1), 1–28.
- Orlikowski, W. J., & Iacono, C. S. (2001). Research Commentary: Desperately Seeking the “IT” in IT Research - A Call to Theorizing the IT Artifact. *Information Systems Research*, 12(2), 121–134.
- Orlikowski, W. J., & Scott, S. V. (2008). Sociomateriality: Challenging the Separation of Technology, Work and Organization. *The Academy of Management Annals*, 2(1), 433–474.
- Orlikowski, W. J., & Scott, S. V. (2015). The Algorithm and the Crowd: Considering the Materiality of Service Innovation. *MIS Quarterly*, 39(1), 201–216.
- Payne, G., & Payne, J. (2004). *Key concepts in social research*. London: SAGE Publications.
- Pickering, A. (1993). The Mangle of Practice: Agency and Emergence in the Sociology of Science. *American Journal of Sociology*, 99(3), 559–589.
- Pinch, T. J., & Bijker, W. E. (1987). The social construction of facts and artifacts: Or how the sociology of science and the sociology of technology might benefit each other. *The Social Constructions of Technological Systems: New Directions in the Sociology and History of Technology*, 17, 1–6.
- Provost, S. M., & Jarvenpaa, S. L. (2014). Creativity at the Margins: Exploring Social and Technical Marginality in Novel Idea Generation. In *Proceedings of the 2014 47th Hawaii*

- International Conference on System Sciences* (pp. 191–200). Waikoloa: IEEE Computer Society Washington.
- Ralph, P., & Wand, Y. (2009). A Proposal for a Formal Definition of the Design Concept. In K. Lyytinen, P. Loucopoulos, J. Mylopoulos, & B. Robinson (Eds.), *Design Requirements Engineering: A Ten-Year Perspective* (pp. 103–136). Berlin: Springer.
- relatum. (n.d.). In *Collins English Dictionary - Complete & Unabridged 10th Edition*. HarperCollins Publishers. Retrieved from <http://dictionary.reference.com/browse/relatum>
- Robey, D. (1996). Research commentary: Diversity in information systems research: Threat, promise, and responsibility. *Information Systems Research*, 7(4), 400–408.
- Ryan, G. W., & Bernard, H. R. (2003). Techniques to Identify Themes. *Field Methods*, 15(1), 85.
- Saldert, C. (2014). Personcentrerade samtal vid kommunikationshinder. In I. Ekman (Ed.), *Personcentrering inom hälso- och sjukvård: Från filosofi till praktik* (pp. 207–225). Stockholm: Liber.
- Sanandaji, N. (2012). *Den innovativa vården* (Vinnova Rapport No. VR 2012:10). Stockholm: Vinnova.
- Sandberg, B., & Aarikka-Stenroos, L. (2014). What makes it so difficult? A systematic review on barriers to radical innovation. *Industrial Marketing Management*, 43(8), 1293–1305.
- Schultze, U. (2017). What kind of world do we want to help make with our theories? *Information and Organization*, 27(1), 60–66.
- Schumpeter, J. (1934). *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle* (originally published 1911). Cambridge: Harvard University Press.
- Scott, S. V., & Orlikowski, W. J. (2013). Sociomateriality — taking the wrong turning? A response to Mutch. *Information and Organization*, 23(2), 77–80.
- Scott, S. V., & Orlikowski, W. J. (2014). Entanglements in Practice: Performing Anonymity Through Social Media. *MIS Quarterly*, 38(3), 873–893.
- Sefyrin, J. (2010). *Sitting on the Fence: Critical Explorations of Participatory Practices in IT Design* (Dissertation). Mittuniversitetet, Sundsvall.
- Sein, M. K., Henfridsson, O., Purao, S., Rossi, M., & Lindgren, R. (2011). Action design research. *MIS Quarterly*, 35(1), 37–56.
- Sele, K. (2012). *The Role of Sociomaterial Practices in Becoming and Staying Innovative: The AI Lab Case* (Dissertation). University of St. Gallen, St. Gallen.
- SFS 2014:821. (2014). *Patientlag*. Stockholm: Socialdepartementet.
- Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information*, 22(2), 63–75.
- Smith, E. E. (2001). Cognitive Psychology: History. In N. J. Smelser & P. B. Baltes (Eds.), *International Encyclopedia of the Social & Behavioral Sciences* (pp. 2140–2147). Oxford: Pergamon.

- Stake, R. E. (1994). Case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research*. (pp. 236–247). Thousand Oaks: Sage Publications, Inc.
- Steering wheel. (2016, October 6). In *Wikipedia*. Retrieved from https://en.wikipedia.org/w/index.php?title=Steering_wheel&oldid=742858395
- Stolterman, E. (1991). *Designarbetets dolda rationalitet: en studie av metodik och praktik inom systemutveckling* (Dissertation). Umeå universitet, Umeå.
- Suchman, L. (2007). *Human-machine reconfigurations: Plans and situated actions*. Cambridge: Cambridge University Press.
- Teece, D. J. (1996). Firm organization, industrial structure, and technological innovation. *Journal of Economic Behavior & Organization*, 31(2), 193–224.
- Terzidis, K. (2007). The Etymology of Design: Pre-Socratic Perspective. *Design Issues*, 23(4), 69–78.
- Thakur, R., Hsu, S. H. Y., & Fontenot, G. (2012). Innovation in healthcare: Issues and future trends. *Journal of Business Research*, 65(4), 562–569.
- Topol, E. J. (2010). Transforming medicine via digital innovation. *Science Translational Medicine*, 2(16), 16cm4, 1–3.
- Tunçalp, D. (2016). Questioning the ontology of sociomateriality: a critical realist perspective. *Management Decision*, 54(5), 1073–1087.
- van Amstel, F. M. C., Hartmann, T., van der Voort, M. C., & Dewulf, G. P. M. R. (2016). The social production of design space. *Design Studies*, 46, 199–225.
- Van de Ven, A. H. (2007). *Engaged Scholarship: A Guide for Organizational and Social Research*. Oxford: Oxford University Press.
- Venkatesh, V., Brown, S. A., & Bala, H. (2013). Bridging the qualitative-quantitative divide: Guidelines for conducting mixed methods research in information systems. *MIS Quarterly*, 37(1), 21–54.
- Verganti, R. (2008). Design, Meanings, and Radical Innovation: A Metamodel and a Research Agenda. *Journal of Product Innovation Management*, 25(5), 436–456.
- Verganti, R., & Öberg, Å. (2013). Interpreting and envisioning — A hermeneutic framework to look at radical innovation of meanings. *Industrial Marketing Management*, 42, 86–95.
- VR. (2002). *Forskningsetiska principer inom humanistisk-samhällsvetenskaplig forskning*. Stockholm: Vetenskapsrådet.
- VR. (2011). *Good Research Practice* (Vetenskapsrådets rapportserie No. 3:2011). Stockholm: Vetenskapsrådet.
- Walls, J., Widmeyer, G. R., & Sawy, O. A. E. (1992). Building an Information System Design Theory for Vigilant EIS. *Information Systems Research*, 3(1), 36–59.
- Walsham, G. (1995). Interpretive case studies in IS research: Nature and method. *European Journal of Information Systems*, 4(2), 74–81.
- Walsham, G. (2012). Are we making a better world with ICTs? Reflections on a future agenda for the IS field. *Journal of Information Technology*, 27(2), 87–93.
- Wassrin, S., Lindgren, I., & Melin, U. (2015). Open innovation contests for improving healthcare – An explorative case study focusing on challenges in a testbed initiative.

- In E. Tambouris et al. (Ed.), *14th IFIP WG 8.5 International Conference, Electronic Government (EGOV) 2015, Proceedings* (pp. 91–104). Thessaloniki, Greece: IFIP International Federation for Information Processing.
- Wiley, J. (1998). Expertise as mental set: The effects of domain knowledge in creative problem solving. *Memory & Cognition*, 26(4), 716–730.
- Wilsford, D. (1994). Path Dependency, or Why History Makes It Difficult but Not Impossible to Reform Health Care Systems in a Big Way. *Journal of Public Policy*, (3), 251.
- Yin, R. K. (2013). *Case Study Research: Design and Methods* (Fifth Edition). Los Angeles: SAGE Publications, Inc.
- Youmans, R. J., & Arciszewski, T. (2014). Design fixation: Classifications and modern methods of prevention. *AI EDAM*, 28(2), 129–137.
- Zaman, B., & Felt, E. (2016). Understanding information system innovation: Moving beyond adoption and diffusion. In *Proceedings of the 27th Australasian Conference on Information Systems (ACIS 2016), 5-7 December 2016*. Wollongong, N.S.W.

Appendix A – Interview guide

Intervjuguide Innovationstävlingen (*Interview guide Innovation contest*)

- Kan du berätta lite om din roll i innovationstävlingen?
Could you tell me a bit about your role in the innovation contest?
- Hur kom det sig att ni bestämde er för att starta en tävling av detta slag? (Har de erfarenheter av något liknande sedan tidigare?)
How come you decided to start a contest of this kind? (Do they have prior experiences of something similar?)
- Vad är en innovation för dig?
What does innovation mean to you?
- Vilka förväntningar hade du på tävlingen innan den började?
What expectations did you have of the contest before it started?
- Kan du beskriva vad syftet med tävlingen har varit? (Vilket problem skulle lösas?)
Could you describe the aim of the contest? (What problem was to be solved?)
- Varför tror du att ni inte fick mer än ett tävlande lag?
Why do you think you only got one competing team?
- Vilka tror du har kompetens att finna en lösning på utmaningen? Vad krävs?
Who has the competence to find a solution to the challenge? What does it take?
- Vilken/vilka målgrupper har ni haft?
What target groups have you had?
- Hur ser du på incitamenten för att vara med i tävlingen? Vilka tror du skulle vilja vara med i tävlingen och varför?
What is your view on incentives to join the contest? Who do you think would like to be a part of the contest and why?
 - Har ni tänkt på hur ni väcker intresse?
Have you thought about how to attract interest?
- Hur upplever du tävlingens utfall? Är du nöjd?
What is your experience of the result of the contest? Are you satisfied?
- Utmaningen var att hitta en bra metod för att utvärdera människors förmåga att köra bil säkert efter att de drabbats av någon typ av hjärnskada: Har innovationstävlingen

mynnat ut i ”ett sätt att enkelt, pålitligt och kostnadseffektivt bedöma en persons förmåga att köra bil efter att de drabbats av en hjärnskada”?

The challenge was to find a good method to evaluate people’s ability to safely drive a car after being subject to some kind of brain injury: Do you think that the innovation contest has resulted in “an easy, safe and cost effective way to assess a person’s ability to drive a car after being subject to brain injury”?⁵

- Varför? Varför inte? Vad tror du att det beror på?

Why? Why not? Why do you think that is?

- Har ni dragit några lärdomar av det här projektet? Vilka?

Have you learned anything from this project? What?

- Vad skulle ni gjort annorlunda idag?

What would you have done differently today?

- Finns det något mer som du vill tillägga, utöver det som vi har pratat om nu?

Is there anything that you would like to add, apart from what we have talked about?

⁵ The statement and the quote come from the contest rules written by the contest project team.

Appendix B – List of requirements

#	English translation	Swedish original
1	The method should have ecological validity for car driving, i.e. the test person should experience that the test is relevant for the activity of car driving.	Metoden ska ha ekologisk validitet för bilkörning, dvs. testpersonen ska uppleva att genomförandet är relevant för aktiviteten bilkörning.
2	It should be possible for test persons with various disabilities, e.g. one-sided paralysis (i.e. can only use arm/leg on one side) or reduced fine motor skills, to perform the test task.	Testuppgiften ska kunna genomföras av testpersoner med olika funktionsnedsättningar, ex halvsidesförlamade (dvs. bara kan använda ena sidans arm/ben) eller med nedsatt finmotorik.
3	It should be possible to use the method in healthcare without the need for technical specialist knowledge for configuring the equipment.	Metoden ska kunna användas inom sjukvården utan behov av teknisk specialistkunskap för konfigurering av utrustningen.
4	The method should deliver reliable test results regardless of "test leader" and be sensitive enough to identify deviations in the performance of the test subject.	Metoden ska leverera tillförlitliga testresultat oavsett "testledare" och vara tillräckligt känslig för att identifiera avvikelser i prestation hos testpersonen.
5	It should be possible to use the method standalone/offline without connection to internet or external storage.	Metoden ska kunna användas fristående/offline utan uppkoppling mot internet eller extern lagring.
6	The method should have capacity to conduct at least 4-5 examinations per day.	Metoden ska ha kapacitet genomföra åtminstone 4-5 undersökningar per dag.
7	It should be possible to carry out and assess the different phases of the test in their entirety or in parts.	De olika ingående delmomenten ska kunna genomföras och bedömas i sin helhet eller i avgränsade delar.
8	It should be possible to partly tailor an examination to the one being examined.	En undersökning ska i viss utsträckning kunna skräddarsys efter den som ska undersökas.
	<ul style="list-style-type: none"> - Phases should be configurable for different time periods in order to capture difficulty with concentration over time. 	<ul style="list-style-type: none"> - Delmoment ska kunna konfigureras för olika tidsåtgång i syfte att fånga svårighet med koncentration över tid. - Det ska finnas delmoment för att pröva på testet och skapa förståelse (träningsdel) för dess genomförande.

<ul style="list-style-type: none"> - There should be trial runs to create an understanding (practice part) for the test. - It should be possible to flexibly combine the phases into a complete test. 	<ul style="list-style-type: none"> - Det ska gå att flexibelt kunna kombinera delmoment till ett komplett test.
<p>9 It should be possible to store at least 100 examinations before they need to be deleted from the internal storage solution.</p>	<p>Volymmässigt ska minst 100 undersökningar kunna lagras innan de behöver raderas från den interna lagerlösningen.</p>
<p>10 Generated test data should be transferable from the equipment to a personal computer and/or an integrated electronic health record.</p>	<p>Genererade testdata ska vara överförbara från utrustningen till en persondator och/eller gemensamt journalsystem.</p>
<p>11 Test data should be exportable to appropriate known file formats, such as comma-separated values (CSVs) or XML for transfer to personal computer.</p>	<p>Testdata ska i viss utsträckning vara exporterbar till lämpliga kända filformat såsom CSV (comma-separated values) eller XML för överföring till persondator.</p>
<p>12 It should be possible to handle personal data and other relevant in-data for the description of the test person.</p>	<p>Metoden ska kunna hantera personuppgifter och andra relevanta in-data för beskrivning av testpersonen.</p>
<p>13 After completion of the test, it should be possible to deliver test data and comparative values in predetermined reports (numerically, graphically).</p>	<p>Metoden ska efter genomförd testning kunna leverera testdata och jämförelsevärden i förutbestämda rapporter (numeriskt, grafiskt).</p>
<p>14 Data is to be regarded as medical records why storage and availability have to be secure and handled in accordance with the Patient Data Act and the Personal Data Act's guidelines.</p>	<p>Data är att betrakta som journaldata varför säkerhet i lagring och tillgänglighet ska säkerställas i enlighet med Patientdatalagen samt Personuppgiftslagens riktlinjer.</p>